14 Oyster Recovery: Biology, Economics, and Regulations

Convenor: Dr. Bonnie Brown

Toward a Sustainable Coastal Watershed:
The Chesapeake Experiment. Proceedings of a Conference
1-3 June 1994. Norfolk, VA
Chesapeake Research Consortium Publication No. 149

The Precarious State of the Chesapeake Public Oyster Resource

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Abstract: The 243,000 acres of Virginia's public oyster reefs (a.k.a. the Baylor Grounds) have been extremely productive of usable and saleable (market and seed) oysters (*Crassostrea virginica*), oyster shells and oyster shell by-products. Archaeological remains and historical records show that they have yielded great numbers of whole oysters, oyster meats, oyster "seed" and shell since the Chesapeake was formed some 3,000 years BP. In the last century their natural productivity, as indicated by commercial harvest records (the only long-term data available), has declined markedly. In 1904, Virginia's total market (adult) oyster harvest was about 7.6 million bushels (mostly from public grounds). By 1930, roughly a quarter-century later, the harvest from public grounds was some 1 million Va. bu. — somewhat less than a seven-fold decline from the total of 1904. By 1957, again about a quarter-century later, the public market oyster harvest was 586,000 Va. bu. — about a ten-fold reduction. This was two years before mortalities attributed to "MSX" were observed in the Chesapeake. Disease did not cause these long-term declines! Neither increasing, but ineffectual, management efforts nor public ostreiculture prevented them. The downward trend continues.

Of the 243,000 acres of Virginia's public grounds, 199,000 are in the Chesapeake and its tributary estuaries. During the 1993-94 harvest year, only 5,484 Va. bushels of market oysters were recorded from the reefs in all of those 19,000 acres of public grounds. Of them, 5,173 Va. bushels came from about 3,500 acres of James River "seed" oyster beds above Wreck Shoal. The rest of the Baylor acres in the Chesapeake, some 196,000 acres, produced only 311 bushels. As an economic entity Virginia's public oyster resource outside of the James seems economically defunct and the James is fading fast away.

The oyster resources of Maryland (and its Potomac River) have experienced the same long-term downward trends. Peaking some 20 or so years before Virginia's at over 15 million Md. bu. in 1884-85, Maryland's recorded public market oyster harvests have declined more slowly than Virginia's. But, like Virginia's, they have dropped despite a century or more of management efforts and investments of considerable amounts of money in attempts to arrest (but, apparently, not to reverse) that decline. In 1895-96, a mere 11 years after the peak, the recorded harvest was about 7,000,000 Md. bu. — a 50% or two-fold decline. By 1920, about 4,500,000 Md bushels. (30% of the 1884-85 high) were taken and 50 years later in 1970-71, some 2.5 million (about 17%) were reported. This approximately six-fold drop from the 1884-85 high occurred at least 10 years before oyster mortalities attributed to the two diseases had a significant impact in Maryland waters. In harvest year 1993-94, the recorded Maryland market oyster harvest was down to 75,633 Md. bu., or about 0.5% of the 1884-85 peak. These declines would have come earlier and been more severe had not large influxes of public and special fund monies gone into repletion (shell and seed planting) of the public rocks.

The public oyster resources of both Maryland and Virginia, as indicated by

recorded market oyster harvests and the condition of the reef habitats, are severely reduced compared with their condition a century ago. Because the public grounds of both states encompass the best-quality oyster-growing bottoms of the Chesapeake; bottoms that in several millennia since the last ice age had developed billions of animals agglomerated in hundreds of up-thrusting reefs, it is well to ask what happened. How did this condition develop? After all, its coming was predicted by several researchers over 100 years ago, and remedies (and preventatives) were available and recommended even then! Some were tried and millions of public dollars were spent on legislation, regulation, enforcement, and remediation attempts. Ultimately, these efforts failed to restore falling productivity. We ask why.

Review and analysis of available data and historical information reveal several contributing factors. But the important ones are not those society, and science, have usually focused upon. This review prompts the conclusion that the principal causes of the long-term decline in Chesapeake Bay oyster populations on the public grounds are neither disease nor pollution but persistent overharvesting and its consequent impact on broodstock size and composition, negative genetic impact, and associated habitat destruction. Because the state fishery management agencies are responsible for controlling harvesting activities on the public oyster reefs, their failure, their inability, to control harvesting pressure effectively is the first-order cause of the impending economic demise of the public oyster resource.

INTRODUCTION

"We have wasted our inheritance by improvidence and mismanagement and blind confidence . . ." (Brooks, 1891). The eastern, or Virginia, oyster, *Crassostrea virginica* Gmelin, is a highly fecund, hardy, and persistent animal. It has been well tested in the crucible of evolution for several million years and more recently by the extensive environmental fluctuations occurring throughout a cycle of at least four Ice Ages in as many "Chesapeakes". It is quite tolerant of adverse environmental challenges. Predation, disease, drought, flood and other natural death-causing factors are not new to the Chesapeake oyster. Highly successful in "our" Chesapeake Bay for some 3,000 years (Schubel 1981), it has survived all hazards and challenges over the millennia.

Studies indicate that "Chesapeake area" aborigines employed oysters as food during the entire 18,000 to 20,000 years, or so, of the last oceanic transgression (Barber 1979). In 1607 arriving European settlers found great banks or reefs of oysters. Many of them breached the surface at various low-water stages (Wharton 1957). Some have disappeared from the intertidal within the last 125 years. Until about 1830 ,Chesapeake natural oyster populations seemed to be increasing in the face of growing human predation or, at least, holding their own. However, since then, especially since around 1870 or 1880, they have not been able to do so (Stevenson 1894). For over 120 years since peak production years of the late 1880s, the downward trend in the Chesapeake natural oyster population, as evidenced by recorded harvest data, has persisted. More extensive and more accurate industry-dependent and industry-independent data gathered in the last four or five decades confirm this dismal picture.

Commercially important, *C. virginica* has provided the resource-base of considerable Chesapeake economic activity for over two centuries. For much of that time, it was primarily self-sustaining: It was a self-renewing (but diminishing as harvesting increased) resource, requiring little or no direct maintenance. Such a potentially limitless "gold mine" deserved careful husbanding. It did not get it! It could have continued to produce year after year at very little cost, but did not.

The public oyster grounds of Virginia (commonly called the Baylor Survey Grounds, or Baylor Grounds, though additions have been made to them since Lt. J. B. Baylor published the results of his landmark survey in 1894) have been the source of most commercial oyster production in the commonwealth. Whether harvested by public oystermen or replanted and grown by private oyster planters, over 90 % of all market oysters taken and sold throughout history have come directly as marketable adults or as seed from the oyster reefs of the public grounds. The same is true of yields from public grounds in Maryland, whose boundaries were established by a series of surveys conducted in the early 1900s and reported by C. C. Yates (1913). Though recorded production of market oysters from the public oyster reefs of Maryland's upper Bay and tributaries (including the Potomac River) had begun to drop some 25 years before the Yates surveys, while Virginia's had yet to peak, oyster populations in the Bay had already displayed signs of overharvest as larger individuals disappeared from catches and catch-per-unit-effort decreased on exploited reefs (Stevenson 1894).

Over the last two centuries the once-massive Chesapeake reefs and the self-renewing populations of living oysters they produced year in and year out provided local oyster harvesters with marketable edible animals. They also provided oystermen with seed to be sold to private planters who, on bottoms leased from the public, produced market oysters. Out-of-state harvesters and buyers, sometimes as many as 2,000 or more dredge and buy boats, removed millions of bushels of market and seed oysters as well. Many were not reported or recorded. These same oyster reefs supplied uncounted millions of tons of shells for use in road building (whole shells), chemical processing, construction and agriculture (ground and burnt lime) and poultry husbandry (shell grit).

In both states the public oyster grounds and the oysters they produce belong, ultimately, to all citizens and their posterity. As well, the large majority of grounds leased by private planters (far fewer in Maryland than in Virginia) belong initially and ultimately to the general citizenry. Thus, harvesters and leaseholders alike have been and are dependent upon the public largesse. This cogent point was made quite strongly by Virginia's conservative and arguably most powerful non-Colonial governor, Harry Flood Byrd, who, in a communication to the General Assembly over 65 years ago said; "...certainly the people of Virginia as a whole have a right to demand that this great State asset not be made the football of unreasoning prejudice either on the part of the planters or of the tongers and to the short-sighted policy of ruthless extinction." (Byrd 1928)

Unfortunately, users and public managers continued to ignore this important fact and behaved as though only the harvesters, buyers, planters, processors, and sellers had rights to the resource and to the proceeds and ecological benefits therefrom and the potential thereof. They still do! This narrow operational viewpoint has never been biologically, morally, or legally justified. It is not now and should be abandoned! The people's (and posterity's) rights as owners should figure prominently in the management process. They are the stockholders, the owners, of the resource base.

As the record shows, managers and harvesters alike also have ignored the universal truth that no economically valuable public, common-property, biological resource can withstand continual, inadequately controlled harvesting for long. Several once plentiful Chesapeake marine/estuarine fishery

Figure 1. Maryland market oyster production by harvest season (public and private). Maryland oysterman have sucessfully fought leasing throughout the years. Less than 10,000 acres are under lease. Private production has been and is significant. Bars represent public harvests, essentially.

Figure 2. Chesapeake region oyster landings by state.

Figure 3. Virginia market oyster landing for selected years 1880 -1970.

Figure 4. Virginia public market oyster production by harvest season.

resources have been harvested to or beyond the brink of economic extinction. Perhaps the most notable are the two sturgeons now ranked as threatened species (*Acipenser brevirostrum* and *A. oxyrhynchus)*, the sheepshead (*Archosargus probatocephalus*) and the American shad (*Alosa sapidissima)*: Others show signs of growing troubles (White, 1982). The striped bass (*Morone saxatilis*) almost made the list of economically extinct finfishes several years ago. Fortunately, severe reduction of commercial and sport harvesting forced by the Atlantic States Marine Fisheries Commission and the federal government, allowed its recovery. Control of fishing pressure on the striped bass enhanced its relatively rapid recovery. This success story should provide a clear example of the benefits of harvest control.

The Chesapeake oyster population has held out against relatively increasing harvesting pressures longer than most species. It has sustained overharvest for well over a century ,but the apparently inevitable economic demise of the Chesapeake's "golden goose" seems about to happen.

Evidence that the public oyster resource, once deemed inexhaustible by many, is about to succumb – to "play out", is exceedingly strong. Unfortunately, some public managers and industry representatives remain unwilling to recognize this situation publicly. Even more are unwilling to accept the primary, long-term causes – overharvesting and the habitat (oyster reef) destruction associated therewith – so well established by a number of socioeconomic and scientific studies (Stevenson 1894, Moore 1910, Loosanoff 1932, Kennedy and Breisch 1983, Rothschild et al. 1994, Hargis and Haven unpublished reports, and many others).

An example of this mindset or attitude was provided in the Commentary section of the *Bay Journal* recently by two state officials, who argued that the cause of the oyster decline was disease and not management (Jensen and Travelstead 1992). In doing so both, who are fisheries managers for Maryland and Virginia, respectively, were either operating from an extremely narrow viewpoint, or using a carefully contrived interpretive "strawman" not obvious to readers, or they were misinformed or mistaken. Whichever the case they seem to have ignored or glossed over several important and highly pertinent details in preparing their commentary. The most important of them is that recorded market oyster harvests from Maryland's public oyster grounds have been in a general state of decline since 1884-85 (figures 1 and 2), followed by those of Virginia, which have dropped since 1904 (figures 2, 3, and 4). Also, and unfortunately for their argument, the two prominent causative agents of disease among Chesapeake oyster populations *Perkinsus marinus*, widely accepted as the cause of Dermo disease, and *Haplosporidium nelsoni*, related to MSX disease, did not cause numerically or economically significant mortalities in the general oyster population of Maryland waters until around harvest year 1981-82, some 100 years after recorded market oyster harvests had begun their long decline (figure 1). Though some oyster populations in Virginia's lower Bay, with its higher salinities, experienced "significant" oyster mortalities attributed to MSX some 20 years earlier than Maryland (Dermo was already present in some Virginia oyster populations and had presumably been "accommodated to" by affected public oyster populations), the decline in recorded harvests had begun at least 50 years before notable mortalities attributed to either disease were reported. Clearly, despite the arguments of these two fishery managers of the Chesapeake Bay states (and of some industry representatives or apologists) to the contrary, disease has not been the cause of the long-term decline of Bay "natural" oyster populations, as reflected in the recorded market oyster harvests from public grounds in either state. Also, they apparently chose to ignore two important fishery management

[1]Harvest avoid culling whenever possible. They also avoid sulling in areas being harvested to reduce chances of refift rejects. In either caces, reefs being harvested are reduced. Reduction of reefs also alters their geophysical propert

[2]Though purposeful removal of shells themselves for use in road building, lime production, and poultry grit, once commo permitted, shells continue to be removed by harvesting of mature and seed oysters, and the shell-replacement capabilit

Table 1. Effects of overharvesting on oyster populations and oyster reefs.

facts:
(1) harvesters should be allowed to harvest no more target individuals of any population than that population can replace under the ecological circumstances pertaining, and
(2) mortality by disease or any other cause must be factored into the equations used to establish harvest limits or quotas.

A few management (and industry) apologists have even argued that reports of dwindling market oyster harvests are not actually indicative of dwindling populations of oysters on public bottoms, claiming that there are as many individual oysters in the Chesapeake now as there ever were. But this claim is patently ridiculous. Numbers of adult, market-sized oysters (whether 2 1/2" or 3" in maximum shell dimension) are down in both states at this writing. Were they not more would have been caught by experienced harvesters actively seeking these size groups. But catch of market oysters per unit effort has been dropping. This means that numbers of larger, more fecund individuals in the remaining populations are down. As well, the overall reduction of brood stock undoubtedly caused reduction in larvae, spatfall, and adults – a snowballing effect. Further, functional sex ratios may have been altered by constant removal of larger individuals because *C. virginica* is reported to be a protandrous hermaphrodite (i.e., male when younger and smaller and female when older and larger). In fact, overall populations of larger, market-sized, and the younger and smaller individuals called "smalls" by some are severely reduced in most places. Spatfall is down as well in many systems.

Probably the most serious long-term consequence of overharvesting has been habitat destruction. The Chesapeake oyster's "favored" habitat, the oyster reefs, has been reduced. In both states, most once-massive, up-thrusting, surface-breaching oyster reefs are mere hillocks or "bumps" on the bottom. In fact, many formerly prominent reefs, "planed- or nibbled-away" by decades of harvesting by dredge and tong, have become silted over and can no longer sustain appreciable numbers of living oysters. Some vanishing reefs are well below the surface of the bottoms and can no longer "catch" setting-stage larvae or even be located without probing or echo sounding. Destruction of the reefs has been a disaster of the first magnitude since with them went the survivability of the self-renewing populations that sustained the reefs, themselves, and the depredations of industry. See table 1.

RECORDED MARKET OYSTER CATCHES: THE BASIS OF THIS ANALYSIS

This study, designed to determine what went awry, is focused upon the natural, formerly self-renewing oyster populations residing upon the public oyster reefs of Chesapeake Bay. They have been the basis of most public market oyster production in the Chesapeake and still are, even though production is now almost non-existent – comparatively. This report deals with the public oyster resources and the industry dependent thereon! Reference to private planting is only supplemental. Background information has been gleaned from a review of pertinent historical or scientific literature and from personal experiences of some 40 years each as marine scientists, fisheries advisers, and consultants. Additionally, one of us (Hargis) served as a fisheries manager.

For numerical data, we must rely heavily on available records of market oyster harvests to indicate the long-term status of the natural, self-renewing populations of the resource. We realize that such data are fishery-dependent and may contain certain industry-related biases. However, significant fishery-independent data have not been available until relatively recently.

Historical accounts contain the only quantitative data available for the early period. Harvest records collected by the state and federal government cover much of the present century. Together, they provide the only long-term numerical indicators. Whatever their shortcomings, recorded harvests are generally reflective of the state of the resource during the period of harvest in most years and are useful in establishing and identifying trends. Relative comparisons made therefrom are considered meaningful (Christy 1964, Kennedy and Breisch 1983). It is no accident that recent, industry-independent, objective estimates of current population levels of James River seed area populations are down (Haven et al. 1978, Hargis and Haven 1988a, Roger Mann, personal communication).

At least one Chesapeake fishery manager has recently opined publicly that the estimates of harvests in Maryland in the period prior to 1900 or so were high, apparently inferring thereby that the declines shown by the data for Maryland (figure 1) have not been as significant as they appear and that the effects of overharvesting in the late 1800s and early 1900s were not as severe as some have claimed. However, many fishery statisticians and scientists have concluded that recorded Chesapeake oyster harvests actually have been under-reported and are, therefore, conservative – probably highly so. Our experiences and studies confirm this conclusion (Haven et al. 1978). The reasons for these conclusions are simple. Reporting has been largely voluntary and based upon industry-generated and provided numbers with little verification. Throughout most of the history of the fishery, most harvester/buyer transactions have been in cash, the monitoring of which is impossible. Because of the state and federal tax implications of numerical catch data, at-landing purchases, or even records of processed products, and the desire of many industry participants to minimize accountable transactions and tax liabilities, the likelihood that data regarding harvests and buyer purchases have been anything other than the lowest and most conservative possible is vanishingly small. This conclusion was verified most recently when a leading upper-Bay waterman was reported to have insisted publicly that the low 1993-94 Maryland market oyster harvest of only 75,633 Md. bu. was deliberately underreported by fellow harvesters.

Some contend that dwindling market demand for oysters, and not declining oyster resources, has been responsible for part of the downturn in market oyster harvests in the Chesapeake region over the years. This argument is specious. Extensive industry records and related studies show that regional and national demand did not decline through most of the last 150 years, even while harvests of public oysters in the northeastern and mid-Atlantic states and in the Chesapeake region dropped. Historically, increasing national demand forced northern harvesters southward in the quest for new resources to pillage during the early 1800s (Ingersoll 1881, Stevenson, 1894). Further, all along the Atlantic coast of the United States, continuing demand spurred “artificial” culture of oysters after local self-renewing populations on public oyster reefs had been “mined out.” In some eastern states ostreiculture increases. Even now (fall 1994), when demand for oysters in the United States actually appears to be declining owing to changing tastes, unfavorable publicity or other consumer-related factors, processors in both Chesapeake Bay states import shucking stocks and shucked oysters from other parts of the United States to meet existing wholesale and retail demands (while at the same time insisting that Chesapeake public beds not be closed). Also, some sales organizations in the United States are importing oysters from abroad. That diminishing demand has not caused the long-term decline in Chesapeake public oyster harvests can be safely assumed! The recording agencies of the states and federal government employ the slightly different reporting measures —the Virginia and Maryland bushels. Following their lead, we do likewise. The difference is slight.

In summary, recorded data based upon harvests are meaningful and useful for year-to-year comparisons of oyster harvests and of the approximate state of the resource as most fishery scientists and managers have done. We are confident in their utility and applicability to the objectives of this study.

The Chesapeake Public Oyster Resource: Its Current Status

For most of the last 150 years or more, changes in size-class composition and catch-per-unit of effort (see Stevenson 1894, pp. 247, 287), and numbers of market-sized individuals in the recorded commercial oyster harvests of the Chesapeake Bay states show that oyster populations on the public oyster reefs have declined. Evidence of this is powerful and persuasive. Essential facts accounting for the drastic reduction of public oyster resources in the Chesapeake (in Maryland) have been available for some time (Ingersoll 1881, Brooks 1891, 1905, Stevenson 1894, Winslow 1881, 1882, 1884, Loosanoff 1932, and others).

As early as the late 1700s, public oyster resources in the Northeast had declined to such low levels owing to overfishing that New England-owned and based sail-powered oyster dredgers invaded the Chesapeake Bay in large numbers. So many appeared each year that Virginia, fearing depletion of its oyster resources (especially by “foreigners”), banned harvest by dredges on its public oyster reefs in 1811. Maryland did the same in 1820. Later both states allowed resumption of dredging with special restrictions on outsiders. But by the time they did, many northern oyster catchers and processors, shippers, and marketers had established business relationships (genuine or spurious) or local businesses in the Chesapeake region to avoid the noncitizen ban. Many actually moved to the Chesapeake after their northern oyster businesses declined or failed. New England surnames became common in Bay fisheries (Stevenson 1894). Dredging continued apace.

This north-to-south migration of the oyster industry continued as New England, middle-Atlantic, and later Chesapeake oyster stocks were depleted. Publicly based oystering operations have shifted ever southward along the western North Atlantic littoral. Oyster populations in Atlantic states south of Virginia are shrinking under the pressure.

The socioeconomic importance of the eastern, or Virginia, oyster (*C. virginica*) to both Bay states is well documented. Over the years, public news media of the Chesapeake region have devoted considerable attention to the oyster resource, its management, its problems, and its future. In the early part of this century, at least 33 editorials treating the socioeconomic and political activities related to oyster management appeared in the *Baltimore Sun* within a 3-month period in the spring of 1914 (Kennedy and Breisch 1983). This level of attention by that newspaper is understandable. The oyster was the basis of many Chesapeake financial fortunes and had sustained over 100,000 people Bay-wide. At that time, Baltimore was the center of oyster processing and distribution in Chesapeake Bay. It was the world leader. Of special importance to the media was the drop in market oyster production from the public oyster reefs (mostly) of the upper Bay from a reported peak of 15 to 16 million Md. bu. in 1884-85 to between 4 million and 5 million Md. bu. in 1914 (figure 1). It was never again to attain the highs of the 19th century.

In Virginia the *Richmond News*

Leader published a series of articles on the declining oyster resource and the industry based thereon in 1930. These articles were accumulated in a booklet (Corson 1930) by that influential newspaper in an attempt to affect public policy concerning oyster management, which was under considerable scrutiny and debate at the time (Byrd 1928). The *News Leader's* series established clearly and convincingly thatVirginia's public oyster resources had been overutilized and the industry based thereon was in decline well before the 1930s. Notably, reported harvest declines in both states had occurred even before toxic pollution, overfertilization, and diseases were identified as significant problems in the Chesapeake.

Market Oyster Harvests from Maryland's Bay Waters

Populations of oysters on the fabled public oyster-producing grounds of Maryland's upper Chesapeake, as reflected by recorded market oyster harvests after 1885, dropped abruptly through the remainder of the 19th century and into the next (figure 1). After declines of over two-fold, or one-half, to some 7,000,000 Md. bu. in 1895-96, only 11 years after the peak of more than 15 million bushels in 1884-85 and between 4 million and 5 million (a three-fold reduction) in 1914, harvests hovered at about 4,500,000 Md. bu. around the early 1920s. Afterward, annual recorded harvests trended more gently downward, with some variation, until 1965-66. By the1970-71 harvest year only 2.5 million bushels were reported. This approximately six-fold drop from the peak harvest of 1884-85 took place at least 10 years before significant mortalities attributed to disease

Figure 5. James River "seed area" harvest of seed and market oysters versus fishing effort. Market oysters (2 1/2 inch over "shell length") did not become the major quarry in the seed area until the 1986-87 harvest year. Scales for fishing effort and catch per day differ from those for catches. (From Virginia Marine Resources Commission data.)

appeared in Maryland oyster populations. As figure 2 verifies, Maryland oyster landings, as reflected by pounds of meats, maintained a downward trend though they had flattened out somewhat from 1971 to 1982, as shown in figure 1. By 1985-86 the annual catch was down to 1,557,091 Md. bu. In harvest year 1993-94 the recorded market oyster harvest dropped abruptly to 75,633 Md. bu., 47,985 bu (or 38.8%) less than the 124,618 bu recorded in 1992-93 and over 13 million Md. bu., or 99.5%, less than in 1884-85. In Maryland, as in Virginia, these declines would have occurred earlier and been more severe had not large influxes of general fund and special fund dollars been spent on the planting of millions of bushels of shells and thousands of bushels of seed in attempts to maintain production on the public reefs. It is difficult to determine if actual rebuilding of the reefs and stocks or merely maintenance of status quo in both was an intended result of this repletion program because harvesting was allowed almost as quickly as market-sized oysters appeared following plantings of shells or seed. Certainly little rebuilding, probably none on most reefs, resulted!

The public oyster bottoms of Maryland are more extensive than Virginia's. At the time of the Yates (1913) survey, they encompassed over 315,000 acres ("natural oyster bars" — 215,845 acres plus 100,000 "known productive" acres, p. 12) versus the some 211,000 acres for Virginia identified by the Baylor Survey (Baylor 1894) in Virginia. (As noted above, additions to the public oyster grounds of Virginia have been made several times since 1894, raising the total to the current level of about 243,000 acres, including those on the Seaside of the Eastern Shore. The same has occurred in Maryland since 1913: Acreage has been added to the original Yates survey.) Because a larger percentage of the public oyster bottoms of Maryland were (and are) more suitable to the survival of oysters than those in Virginia's waters owing to more favorable salinity distribution related to the dominant freshwater contribution of the Susquehanna drainage basin, the continuing decline of market harvests in Maryland is even more significant and the reason(s) for it more difficult to understand.

The Natural History of Public Market Oyster Harvesting from Virginia's Waters

A larger portion of Virginia's some 199,000 acres of public oyster grounds in the Chesapeake basin has been subject to occupation at various times by screwborers (*Urosalpinx cinerea* and *Eupleura caudata*), starfish (*Asterias forbesi*), and other oyster-consuming predators than those of Maryland. The same is true of the oyster diseases, MSX and Dermo. These and similar oyster enemies are normally kept from most of the public oyster grounds of Maryland (and comparable regions in Virginia) by the lower-salinity waters usually prevalent there. But protection related to low salinity breaks down when prolonged drought visits the Chesapeake watershed, especially the Piedmont and mountain regions of central New York, Pennsylvania, Maryland, West Virginia, and Virginia. Significantly lower precipitation there in winter and early spring, reduces spring freshwater inflows from the Susquehanna, Potomac, and James Rivers. Subsequently, salinities of Bay and tributary waters increase as higher-salinity ocean water replacing diminishing freshwater flows encroaches farther and farther up-Bay, upriver and inland. Short dry spells and short wet spells have been the rule in the Chesapeake region since climatological records have been kept, but occasionally a long dry period occurs and salinities in the Bay become higher, intrude farther up-Bay and upriver, and remain there for longer periods. This happened in the decade of the 1980s, and high-salinity waters favoring the two diseases (MSX and Dermo) swept into areas in Maryland and Virginia whose waters are normally of lower salinity. They remained there for long periods. The two diseases spread as well. (Whether their spread was aided by movement of infected seed and adult oysters by public or private planting activities is not clear, but it could have been.) The oysters in those areas had little or no previous experience with either disease and resistance was low to nonexistent in affected populations. Oyster populations in much of Maryland and on many normally low salinity oyster beds in Virginia were significantly affected by disease-related deaths in the 1980s for the first time since oyster harvests have been recorded. Warmer-than-usual winters, which seem to favor attacks of Dermo, also prevailed during much of this period. Mortalities occurred and oyster stocks and catches declined faster and further than by overharvesting alone, but too many market oysters continued to be removed from upper-Bay and other lower-salinity reefs by oystermen. Overharvesting is relative to the ability of the target group to sustain the removals made at the time of harvest, not some previous "happier," higher-productivity time. Disease is a natural factor that must be considered in fishery management!

Total recorded market oyster harvests in Virginia for schocked years from 1890 to 1970 are depicted in figure 3. Total market oyster harvest figures include production from both public reefs and private beds. Reports before 1930-31 did not distinguish between the two effectively. Though private plantings occurred before the Baylor survey was begun in 1892, oyster production before 1925 or so was largely from the public reefs and, therefore, mostly reflects the actual populations on the public grounds whence they were drawn. As leasing grew, private production contributed an increasing proportion of the state's total market oyster production. It is difficult to distinguish exactly how much market oyster production from public oyster reefs and how much from private grounds for this period from the data available to us to this point. Because of this difficulty, we have included a line graph representing the reported leased acreage along with the total "catch" bars from harvest years 1901 to 1970 in figure 3. This allows a comparison between acreage under lease, and presumably planted, and total recorded harvest. Beginning in 1930-31, public and private harvest records were separated and regularly so reported. Therefore, catches from public grounds for the years after 1930 are represented by the hatched areas in figure 3. Those from private leases are stippled. Even so, as the figure shows, not only did harvests from public reefs decline during the period 1904 to 1930-31 but whatever increased private planting occurred (here we presume that increasing acreage under lease meant increased private planting) was never able to compensate for the long-term drop in populations on and catches from public grounds during that time. Had it compensated more effectively, the total harvest bars (heavily outlined) would not have declined as they did. Indeed, except for 1960, the trend of catches from public grounds was definitely downward during the period as it continued to be afterward. Otherwise the total market oyster harvest record during that period would have trended upward instead of downward.

In harvest year 1930-31 (1930), when clear-cut separation of harvests from public reefs and private beds was effected (figure 4), the market oyster harvest from the public grounds alone was down to about 1 millionVa. bushels from the peak of somewhat below the total of 7.5 million Va. bu. reported in 1904. This was at least a seven-fold, or about 87.0%, decrease. As figure 4 shows, the decline in public market oyster harvests continued throughout the entire 28-year period (1930 to 1958) before MSX was identified in oysters from higher salinity portions of Virginia's lower Chesapeake system in 1959-60.

After the 1960-61 harvest season, public market oyster yields dropped still further to about 230,000 Va. bu. in 1961-62 and 280,000 in 1962-63. In 1964-65, they doubled to around 600,000 Va. bu. Thereafter, with fluctuations (probably caused by development of disease resistance to MSX in the populations, or changes in distribution and effectiveness of MSX associated with changes in salinity patterns, or both) market oyster harvests from public oyster reefs continued fairly significant (ranging from about 200,000 to 700,000 Va. bu) but drifted downward until they flattened out at around 300,000 Va. bu. in 1982-83 and remained there through 1985-86, the year that populations and market oyster from harvests outside the James "crashed."

In the 1986-87 harvest year, Virginia's public market oyster catches increased markedly to 501,075 Va. bu. But this upward swing did not mean that harvestable numbers of market-sized individuals had increased in the populations surviving on the public oyster grounds of Virginia. To the contrary, harvestable market oyster populations on public grounds elsewhere in Virginia's Chesapeake waters (or wherever Virginia oystermen usually worked, including those of the Potomac River) had dropped to record lows! As a result, remaining oystermen from all over Virginia descended upon the only still-productive public oyster reefs of Virginia – the seed oyster grounds of the upper James estuary above Wreck Shoals. Consisting of about 3,500 acres of actively-producing oyster reefs out of a total of some 28,000 acres in the entire James system and 199,000 public acres in the entire lower Chesapeake, the "former" seed area produced 342,784 Va. bu of market oysters (obligingly redefined downward at that time for the convenience of the oyster harvesters by VMRC from 3 inches to 2 1/2 inches maximum shell dimension) in 1986-87. For the first time the principal "seed" area of Virginia produced more market oysters than seed and more than all other public reefs. All of the rest of the Baylor Grounds in the Chesapeake (some 196,000 acres) produced only 158,291 Va. bu (or 32% of the total) in that year. In 1987-88 ,even more oystermen came to the former James River seed reefs in search of market-sized oysters but, despite the increase in effort (from 15,754 boat days in 1986-87 to 21,305 in 1987-88), the total market oyster harvest already had begun to drop (to about 297,774 Va. bu in 1987-88) and continued to do so for the next 4 years. This sequence is well illustrated in figure 5. When increased effort produces smaller catches from an otherwise reasonably stable population, overharvesting is the cause.

In 1991, Hargis and Haven (unpublished report) recommended to the Virginia Blue Ribbon Oyster Panel that the Virginia Marine Resources Commission (VMRC) be advised to consider cessation of James River seed area market oyster harvests. But, harvesting pressure on producing reefs was not effectively controlled and the drop continued. Concerned over this disastrous situation, fishery management specialists and scientists from both VMRC and the Virginia Institute of Marine Science (VIMS) urged complete closure of the public oyster reefs of the James River seed reefs to market oyster harvesting in the fall of 1993 to conserve brood stocks. (Paradoxically, seed harvests, removal of small young oysters from the surviving population, were to be allowed to continue). At first, VMRC commissioners agreed and halted market-oyster harvests for almost two months. Unfortunately, pressured by oystermen and their allies and apologists, the Commission reopened the beds to market-oyster harvesting in late February of the 1993-94 harvest season. In harvest year 1993-94, market oyster catches from the James' reefs dropped to a record low. (Only a small part, if any, of this reduced harvest can be attributed to the closure during the "deep winter" months of January and February of 1994.) Market oyster production by the James River public seed beds had all but ceased and those few that were caught were hard to sell as "markets." Total Chesapeake Baylor (public) Grounds market oyster production for the period 1993-94 was 5,484 Va. bu! The James River seed area had produced 5,173, or almost 95%, of that. The other 196,000 acres of Baylor grounds in all of the rest of Virginia's Chesapeake produced only 311 Va. bu! (Similarly, the entire Potomac River yielded only 230 Md. bu. and VA. bu in 1993-94, versus 74,591 in 1992-93 and many more earlier.) It is crystal clear from these data that the James, once the source of most seed planted by private growers, could no longer provide significant quantities of seed were it called upon to do so and probably will not be able to do so for many years.

But, as indicated above, declining market oyster production by the public (Baylor) grounds was not a recent phenomenon. It had been occurring for almost a century. The best example of this is provided by the James River estuary, which contained historically the most productive acreage of public bottom in Virginia. In fact, James River oyster reefs, in the market oyster area (i.e. , below Wreck Shoals) were showing clear signs of depletion (Ingersoll, 1881) well before Dr. H. F. Moore's quantitative survey of 1909. The same was true for the reefs of the seed oyster area (except Wreck Shoals which apparently showed few signs of depletion at that time) (Moore 1910). Unfortunately, populations on all James River market and seed reefs dropped still further during the next 20 years and by 1930 even Wreck Shoals reefs were being depleted (Loosanoff 1932). Marshall (1954) and Hargis (1966) noted additional declines in James River reef topography and structure during the next 20 and 35 years after Loosanoff's report, respectively. Haven et al. (1981) found more signs of damage (and associated population reductions) to the James River market and seed oyster reefs. DeAlteris (1988) quantified damage to the Wreck Shoals reef. Bailey (1941) reported similar declines of public reefs in the York River.

Clearly, the majority of Virginia's Chesapeake Bay public oyster reefs have been overharvested throughout the 20th century, and even before. Today, all are reduced, many are essentially depleted. Fortunately, the 196,000 public grounds outside of the James have been closed by VMRC for about two months at this writing. We wonder how long this closure will continue after semblances of harvestable stocks return. (Judging from past management performance, it won't be for long.) Unfortunately, the James seed area remains open to market and seed oyster harvesting.

The complex relationships between overharvesting, depletion, and degradation of living populations and habitat (reef) destruction are depicted in table 1.

A Brief Review of Management Efforts on the Chesapeake

Kennedy and Breisch (1981 and 1983) presented the history of oyster management efforts in Maryland and provided a critical analysis of the results those management efforts produced or, rather, failed to produce. Their 1983 report, "Sixteen Decades of Political Management of the Oyster Fishery of Maryland's Chesapeake Bay," is the best overall review and evaluation of the problem that has been produced in this century. Rothschild et al. revisited this subject in 1994. Their findings largely reinforce those of Kennedy and Breisch. Unfortunately, Rothschild et al. (1994) opined that hand tongs, not being as destructive as dredges, had not been involved in the reef reductions. In this conclusion, they were mistaken.

With few exceptions shaft tongs have been the principal gear allowed on the public reefs of Virginia and on those in county waters in Maryland during this century. They have been the only harvesting tools allowed on the James seed reefs in recent times. Though shaft (hand) tongs require direct muscle power and may take longer than powered scrapes (light dredges), dredges, or patent tongs, depending of course upon the numbers engaged at any one time, they can and do destroy reef structure.

The most comprehensive study of the Virginia oyster resource, the industry it supported and the management efforts directed at continuing the resource and preserving industry was conducted during the mid-1970s. The results appeared in an extensive report by Haven et al. (1978). Sequels were published by Hargis and Haven (1988a and 1988b).

The reports of Kennedy and Breisch (1981 and 1983), Rothschild et al. (1994), Haven et al. (1978), and Hargis and Haven (1988a and 1988 b) can be consulted for full details of those studies. All provide information useful in the evaluation of the effectiveness of Chesapeake Region public oyster fishery management. It is not necessary to review their findings here, but sufficient to assert that the major conclusions reached therein were adequately supported and justified by the available data and related information cited.

Management by Legislative and/or Executive Regulation —Generally Restrictive and Protective in Intent

Concern for the structural and functional condition and the biological and economic productivity of the public oyster grounds (reefs) of the Chesapeake owing to increasing harvesting activities was expressed in the early 1800s. It was manifested early on by the 1811 prohibition of harvesting of oysters from the public grounds by dredges in Virginia. This protective legislative enactment by the Virginia General Assembly was followed by many more in the next 180 plus years. The legislature of Maryland has been active as well, possibly more so than that of Virginia. It, too, banned dredging in 1920. Oyster police were established in both states after the Civil War. At times machine guns, even cannon, were employed in enforcement attempts. Cull laws were established, as were closed seasons (Everstine 1946, Haven et al. 1978, Kennedy and Breisch 1983). Dredges were reinstated and then limited in both states. In 1879, Virginia again banished dredges from its public reefs (Ingersoll 1881) but allowed its citizens to employ them in the mainstem of the Potomac River. In 1933, issuance of eight Potomac dredging licenses to Virginia oystermen was reported in the annual report of the Virginia Fisheries Commission. In 1934 and succeeding years, none were reported. Hand scrapes continued in use on the Potomac illegally and then legally. Maryland restricted oyster dredges to Bay reefs and allowed only sail as the motive power there. This restriction applied until just recently when dredging by sailboats assisted by their “yawl boats” (motorized push-boats) was permitted for two days a week? By this action, a concession to sailing oyster harvesters, power dredging was restored to Maryland – essentially. Soon, some skipjack captains and crews dredged mostly on “push-boat” days. Total state market oyster harvests, and probably catch-per-boat, declined throughout. The dredge-boat fleet dwindles apace.

Clearly, restrictive management efforts had not worked in either state or on the Potomac River! Public market oyster production continued downward and the condition of the public oyster reefs worsened even though restrictive regulations increased and police forces were strengthened. Unfortunately, actual harvesting pressure was never effectively controlled. Thus, legislative and regulatory aspects of the voluminous and complex, often ad hoc, management programs of both states had clearly failed.

Employment of Ostreiculture as a Means of Replacing Lost Natural Production or Augmenting Production on Public Oyster Reefs

Repeatedly, as human populations have overwhelmed local natural food supplies, "artificial" monoculture has been promoted. Such has happened to the Eastern oyster (*C. virginica*). As natural, self-renewing production on public oyster reefs declined under the harvester's onslaught thoughts of scientists, public managers and some oystermen turned toward replacement by, "forced" culture using techniques already practiced elsewhere. New England oystermen sought seed oysters from New Jersey and Chesapeake waters to "bed" or "plant" at home as early as 1808, probably before (Stevenson 1894). Oyster populations in their own public waters had begun to fail before then and meeting the rising national demand for oysters required more than could be harvested locally.

Exactly when crude ostreiculture (and, as generally practiced, it remains crude) began in the Chesapeake may never be known but its occurrence was officially recognized in 1830 by passage of the One-Acre Planting Law in Maryland. Publicly sanctioned "private" oyster culture using state-owned bottoms had begun.

It did not take long for Maryland's watermen to decide that private oyster culture was not in their best interests. Their long political struggle against private planting began. Recurring skirmishes between public and private oystermen erupted into open political warfare. Gunfire was exchanged occasionally (Wennersten 1981). Opposition by public oystermen and their supporters to private leasing resulted in a decisive defeat of advocates of private ostreiculture in Maryland (Kennedy and Breisch 1983), even though federal and state fishery scientists and managers had strongly urged expansion of the practice in several major reports and two popular books (Brooks 1891, 1905, Stevenson 1894, Winslow 1884, Yates 1913 ,and others). During the latter phase of the battle the *Baltimore Sun* also promoted state encouragement of private culture in 1905 and 1906. Over the next several decades, political maneuvering by and on behalf of Maryland public oystermen effectively forestalled development of private ostreiculture in Maryland's public waters. For all practical purposes, it was frozen (Kennedy and Breisch 1983). Private planting in Maryland's waters remains minuscule, occupying about 9,000 leased acres. At times, state officials have opposed private planting. Some still do.

Judging by what actually transpired afterward, the public oystermen's objections to private ostreiculture were not directed toward the culture part of the equation but to the private portion. Maryland's watermen were quite willing to have the state undertake ostreiculture — on their behalf. As natural production from the public oyster reefs continued to decline (despite cull laws, shell reservations, size limits, closed periods, legislated inefficiency of harvesting methods, and all other protective laws and regulations), the state of Maryland itself undertook programs of public oyster reef repletion under a law passed in 1924. Over time Maryland's repletion program became quite extensive. At first it was financed by a gas tax on work boats and direct appropriations from the state general fund. Later, other oyster-related taxes were involved but general fund subsidies were often predominant, as they are today. (According to Maryland Department of Natural Resources data, from 1980 to 1991, almost 60 years after the first repletion law was enacted, direct-cost expenditures for public grounds repletion activities averaged over $1.7 million per year.) Maryland's oystermen not only benefitted from naturally produced populations on the public's oyster grounds, but harvests from those grounds were augmented by shell and/or seed plantings subsidized by revenues extracted from the entire state citizenry. Maryland's citizens had been taxed to maintain harvests from their own resources and waters. From time to time, even federal funds have been involved. The self-interested influence and power of Maryland's oystermen is nowhere demonstrated quite so clearly as in the public versus private culture debate and in the securing and perpetuation of sizeable public subsidies for themselves. Undoubtedly, many Tidewater politicians earned local approbation thereby.

In Virginia the negative response by public oystermen to general urgings of private culture was less vehement or, more likely, had a lesser effect than in Maryland on legislative and executive action that was more positively attuned to private enterprise. Despite strenuous opposition from oyster tongers, the commonwealth supported the developing private planting effort more forcefully than Maryland and leasing expanded. Virginia businessmen and watermen began occupying state bottoms as early as 1865 in Chincoteague Bay. The practice spread. Confusion resulting from their unsanctioned activities lead to the Baylor Survey in 1892 (reported in Baylor 1894). Even before the survey was reported and officially adopted, "private planting" was already under way. In fact, occupation of state-owned bottoms by private planters (squatting) was largely responsible for the Baylor survey. We do not know how many public acres were illegally occupied by planters. But by 1899, 35,000 acres were reported by the Virginia Board of Fisheries as being legally under private lease. The number grew slowly to 40,400 acres in 1910, 48,014 in 1923, and 56,778 in 1925 (figure 3). For most of this time, public grounds continued to outproduce leased ones. The balance had reversed by the 1930-31 harvest season. During the period from 1931 to 1967, private leases doubled from 63,422 acres to 134,492 acres (Haven et al. 1978). Eventually, market oyster harvests from private plantings exceeded those from the public reefs by 3:1, or more. This situation continued for over 45 years but was again reversed in harvest year 1977-78. Because most of the seed employed by the planters had come from the public reefs of the James River, even the harvests from private plantings have been based upon "natural" production of Virginia's common property reefs.

Considering the public source of most seed (and public ownership of the grounds leased at low cost by private planters), it is obvious that private ostreiculturists have been closely dependent upon the citizenry of Virginia for much of their incomes from that activity. Because leases have always been inexpensive, usually $1.50/acre or less, private planters have been directly subsidized by the general citizenry from the beginning of private ostreiculture. Virginia's citizens have, in reality, subsidized private planters indirectly by making large quantities of juvenile oysters (seed) from public reefs available to public watermen to harvest, generally at low cost compared to the value of market-sized oysters, and sell to planters. For many years, this seed oyster harvesting has been a major factor in population declines and reef destruction in the James River seed area.

Despite the rise of private planting in the Virginia's lower Bay, the commonwealth, too, began a program of state-operated oyster reef replenishment in 1928 (four years after Maryland's was officially enacted) to enable harvesting from the public oyster reefs to continue (1928 Oyster Repletion Act). The Virginia repletion program did not amount to much until 1934-35, when 486,462 Va. bu. of shells were planted, but in biological year 1974-75 became truly significant when it reached 3,481,727 bu. The total shell planted on Chesapeake Bay public reefs from 1962-63 to 1992-93 was about 53.5 million Va. bu., averaging about 1.8 million bu. per year. Significant quantities of seed, also from the public beds, were being planted on public reefs by the early 1970s. From 1962-63 to 1992-93, 2.13 million Va. bu. of seed were planted (an average of 71,000 bu./yr). Had shell and seed plantings not been made during the last 65 years, harvests from the public oyster reefs of Virginia would have dwindled and almost disappeared much earlier than they did. In Virginia, as in Maryland, harvests from public oyster reefs have been substantially supported by the taxpayer-at-large (general fund monies) or by funds from other nonfishery-related sources such as revenues from state-granted rights of way through and over state-owned bottoms, both fresh and estuarine. In the long run, however, publicly-subsidized ostreiculture of Baylor Grounds bottoms did not rebuild or even sustain the public oyster reefs or their dwindling oyster populations in Virginia!

Management-Related Studies

Questions of what has happened to the Chesapeake public oyster resource, of what was the cause (or causes) of its decline, have concerned fishery scientists, fishery managers, and oystermen increasingly in the last century. Lately, the public has become concerned. Such questions have prompted dozens of oyster study groups during this century. Even as this was written several were in action around the Chesapeake. Usually involving considerable debate, much of it either largely inconsequential, incomplete, ill-informed, or individually self-serving, the work of these study groups has resulted in few positive results.

In their second management report, Kennedy and Breisch (1983) discussed details of some of the many studies of the oyster and oyster industry conducted by special legislative and executive study groups in Maryland, such as commissions, special study groups, task forces, and similar bodies. Special surveys and reviews conducted by the U.S. Coast and Geodetic Survey, the U.S. Bureau of the Census and the U.S. Bureau of Fisheries (now the National Marine Fisheries Service) were mentioned, as were those of business-sponsored groups such as the Baltimore Association of Commerce (Fairbanks 1932). Some dated to before 1880. Such efforts increased throughout the 1900s. Some studies resulted in legislation, executive reorganization, regulation, and management plans. An early comprehensive management plan for the Maryland oyster resource and fishery- dependent thereon was developed in 1943. Five years later, Bowman (1948) pronounced it a failure, and in that same year a long-range oyster management plan was promoted (Hammer 1948). There have been several since (Anonymous 1990), and recently a new plan was announced in Maryland. Actual improvements produced by all this activity have been rare and of little long-term effect (Everstine 1946, Kennedy and Breisch 1983).

The same has happened in Virginia (Haven et al. 1978, Hargis and Haven 1988a and 1988b, Anonymous 1989). The Virginia Chamber of Commerce was active. Legislatively mandated studies were conducted in 1928, 1936, 1951, 1961, and 1967; And there were others. A number of legislative and regulatory enactments aimed at improving fisheries management resulted. At least two studies of the Joint Legislative Audit and Review Commission (JLARC), which might be considered Virginia’s equivalent of Congress’ General Accounting Office, have addressed oyster management, at least in part. Recommendations for improved oyster management were included in each (Joint Legislative Audit and Review Commission 1977, 1984). Neither included the essential element — effective management and control of harvesting levels.

In 1991, another review group called the Virginia Blue Ribbon Oyster Panel advanced yet another plan for improvement of the oyster resource and industry, which VMRC received in 1992. The most recent study group, authorized by House Joint Resolution 535 and called "The Virginia Delegation to the Chesapeake Bay Commission on the Condition and Future Prospects of the Shellfish Industry in Virginia" is now "sitting" (fall 1994). A truly positive outcome is difficult to anticipate.

The Potomac River Fisheries Commission (PRFC), the bistate (Maryland and Virginia) compact body that manages oysters in the mainstem of the Potomac River estuary, has sponsored oyster management studies as well (Davis 1974). Little positive management activity has resulted and Potomac oyster yields have continued to decline.

In the works but not yet accepted is a joint, Bay-wide management plan developed and advanced by the Chesapeake Bay Commission, an interstate compact body. The likelihood that it will produce truly improved management activity is problematical.

In summary, a plentitude of studies of problems of oyster resources, the oyster industry, and public management all ostensibly aimed at more effective management of the Bay's oyster resources and revival of the industry they sustained have yielded few detectable positive results The few achieved were usually too little and too late and short-lived! The public resource and industry based thereon waned despite them all. This trend will continue until harvest efforts are properly matched to available populations and recruitment and effectively controlled.

Scientific Understanding, Future Research, and Management

The scientific literature on oysters is extensive. The compilation by Breisch and Kennedy (1980) of relevant world oyster literature listed some 3,781 publications. A great deal of that literature is related to *C. virginica* and the industry it sustains. Kennedy and Breisch (1981) incorporated a substantial bibliography of some 725 relevant publications in their first extensive review of research and management of Maryland's oyster resources. Much pertinent oyster research was accomplished by scientists in Virginia (Hargis and Armitage 1983, Wojcik and Hargis 1987). Undoubtedly, more is required but sufficient scientific knowledge and acumen exist now to allow improvement of oyster resources and habitats in the Chesapeake. They should be used even while additional priority research is accomplished.

Improvement in management-related, scientific research is needed. Of all the research that has been accomplished little, has been devoted to the overall oyster community, to oyster populations in relation to their favored Chesapeake habitats, the upthrusting reefs. This astonishing lack should be remedied as quickly as possible. The reef rehabilitation programs now being planned or conducted should incorporate careful ecological studies.

Recently, it has seemed to us that much oyster research effort has been devoted to subjects likely to contribute little to improved management of public oyster resources. As do other human endeavors, science experiences fads. Like others, scientists move toward research topics which generate funding, position, and prestige and away from those that do not. Unfortunately, research popular with proposal and report reviewers, editors and funding agencies may contribute little to practical management efforts in timely fashion — or even ultimately. Some academic scientists eschew what they consider practical, or applied, science. Many do not like survey or monitoring activities so necessary to effective "practical" research and management. Also, scientists and scientific institutions, anxious to survive and/or to avoid entanglement in public controversy, as so often happens in fishery science and advisory services, choose more neutral research topics. Some fishery scientists, growing tired and disenchanted with the disdainful treatment afforded them by public bodies, study committees, and industry groups, chose other, less-irksome topics for advisory service work or research.

In recent years, some Chesapeake monitoring and survey programs appear to have weakened. Whether because of a waning of interest, declining funds, or deliberate attempts to downplay or disguise the seriously depleted condition of the resource, support for and conduct of careful monitoring of harvests, harvest efforts, population levels, site-specific repletion activities versus site-specific yields, spatfall, predation, disease, and other important ecological factors seem to have declined. They should be increased! Scientifically sound and objective survey and monitoring data are necessary for proper management. Management agencies that do such work must make certain that the conduct, results, and reports of that work are thorough, objective (not deliberately organizationally self-serving), publicly available, and incorporated into positive management efforts as quickly as possible.

Over the past 115 years, findings and recommendations of science have been largely ignored. When accepted, acceptance has been given grudgingly. Brooks (1891,1905), Bowman (1940) and Kennedy and Breisch (1983) have commented cogently on interactions between science, industry and/or management. It has been our experience that legislative and executive commissions, committees, panels, and other study groups usually accord scientists and scientific information short-shrift. In government, the call for and funding of further "studies" often excuses the lack of more positive, effective, and immediate action. Science and scientific information have more often been employed to delay decisions or cover for ineffective management than to improve management. Sufficient scientific knowledge and acumen exist to allow improvement of oyster resources and habitats in the Chesapeake now. They should be used!

In summary, more can be learned about the oyster, its capabilities and requirements. Certain avenues of monitoring and research remain to be travelled and should be. Haven et al. (1978) and Hargis and Haven (1988a) included specific recommendations for both. However, sufficient is known that public management can be improved, beginning now! It is neither necessary nor justified to delay positive action pending new knowledge.

DISCUSSION

Prompted by waning harvests and declining natural populations of *C. virginica* in the Northeast, several studies of local oyster stocks and the oyster fisheries they sustained were undertaken in the United States after the Civil War (Ingersoll 1881). Attention quickly focused on the Chesapeake region (Baylor 1894, Brooks 1891, 1905, Brooks et al. 1884, Stevenson, 1894, Winslow 1881, 1882, 1884). These studies concluded that natural oyster populations (on the public grounds or reefs) of Maryland and Virginia were exhibiting signs of overuse —overfishing. Obviously, burgeoning public oyster resource problems were recognized early. Remedies, some as cogent today as when first made, were offered as early as the 1880s. Very few were followed. Some that were tried even worked and the rate of decline of catches and stocks actually was reduced from time to time (figures 1 and 4): Long-term decline continued.

Numerous studies conducted during this century reinforced the results of those made earlier (Moore 1910, Loosanoff 1932, Haven et al. 1978, Hargis and Haven 1988a,1988 b). They, too, made corrective recommendations. Ultimately, however, the underlying problems were not solved and Chesapeake public oyster stocks and harvests slumped further. Today they are, comparatively speaking, nearly nonexistent.

Comprehending and accepting the precarious state of the Chesapeake Bay oyster resource is difficult, especially since *C. virginica* is a territorialey limited animal, sessile as an adult and one that had accumulated massive, self-renewing populations in the Chesapeake by the time the English settlers arrived. Further, this species thrives best in shallow estuarine waters in large groupings that are readily accessible. Also, oyster beds are easily located physically, can be sampled and evaluated. (Unfortunately, these same advantages are also detriments; because they are accessible and easily located and captured, oysters are readily overharvested.) All stages of the oyster's life cycle are sufficiently understood as to allow the animal to be manipulated with considerable precision in laboratory and overboard experimental situations. In short, it is the most easily observed, taken, and manipulated of the major estuarine fishery resources. If any common-property estuarine fishery resource is amenable to effective management *C. virginica* is!

Failure to prevent overharvesting of such a handy, hardy and malleable resource reflects a major flaw in the capabilities of Virginia and Maryland (and other Atlantic coast states whose "natural," self-renewing oyster populations have been all but obliterated) to manage their natural marine/estuarine fishery resources.

All living species are subject to the "rules" and vagaries of nature. Those of substantial socioeconomic import are strongly affected by pressures from humankind as well. In particular, species of economic significance, like *C. virginica*, are subject to direct and indirect and intentional and unintentional human intervention in their processes, habitats, and life-cycles. Additionally, the economic and political activities of humans and associated rules and regulations impinge upon them. The welfare and future of many fishery organisms are, in fact, at times more closely affected by human activities than by natural events.

Chesapeake oysters are a case in point. The classical signs of overfishing (removal of more individuals than the population could replace naturally each year) had begun to appear in the oyster catches and harvested populations of the upper Chesapeake as early as 1840 or so with the disappearance of larger and older oysters from the catch. Soon, more effort was applied but catch-per-unit-effort dropped (Stevenson 1894). Afterward harvests from natural and formerly self-renewing public oyster reefs declined generally. Fluctuations, sometimes large, in spatfall and survival of various yearclasses (roughly, sizeclasses) continued, frequently confusing the picture, but the downward trend in total annual harvests from public oyster grounds persisted. Generally, despite varying highs and lows in recorded market oyster harvests, the highs were rarely as high as formerly, while the lows trended downward as well. Occasionally, as occurred in Maryland in 1840 ,when beds containing unharvested, or underharvested, stocks known only to few oystermen (or, less likely, to none) were "discovered" in Tangier Sound, catches rose sharply and continued to affect total recorded harvests for some years thereafter (Kennedy and Breisch 1983). (The unfortunate, but usual, side effect of such "windfall" increases [including occasionally occurring large spatfalls or temporarily improved survival-rates] was the easing of public pressures for improved management.) Similar harvest increases also occurred in Virginia from

1978-79 to 1983-84 in Tangier and Pocomoke Sounds ,when dredges (scrapes), temporarily permitted on the public reefs there, made populations hitherto beyond the reach of hand tongs accessible (Whitcomb and Haven 1987). (See figure 4). The same has happened in both states as patent tongs were allowed on deepwater populations. Maryland has even allowed harvesting by divers (as has the PRFC), who can locate and hand pick the largest survivors in comparatively deep waters. Not even large "singles" oysters have been beyond capture in some places. Despite such occurrences, the downward trend was resumed once the new or more accessible beds or yields from more efficient gear played out. (Likewise, resumption of decline has followed both record spatfalls and survival rates.)

Obviously, the populations thus opened to exploitation and subsequently significantly reduced in numbers of mature individuals were not as well able to contribute reproductive materials to the maintenance of their own and nearby populations as before. Even the highly fecund oyster has become so reduced in number and altered in spatial distribution that optimum effective reproduction was impaired. Long-term spatfall declines in the formerly reliable James River seed area are evidence of this. The many effects that overharvesting (overfishing) have on oyster populations and their favored habitats, the naturally self-perpetuating oyster reefs, are itemized in table 1.

Simultaneously with reductions in populations (and sustainable harvest levels) the oyster reefs, themselves declined in height, length, and width (circumference), and surface area as "dead" shells were removed along with the shells (and meats, or soft bodies) of living oysters. As individual living oysters were removed by harvesters, their shell-producing capabilities left with them. Present and future cultch was mined away and the living oysters that, if left in place, would have provided fresh shells to continue reef "growth" and provide new cultch when they died, were continually reduced (Stevenson 1894, Moore 1910, Marshall 1954, Loosanoff 1932, and Hargis and Haven, unpublished). At the same time the genetic quality of the remaining populations was being reduced. Stevenson noted these effects 100 years ago when he wrote;"This decrease in the size of the oysters is of more consequence than its effect on the markets [the decline of the larger extra select class of market oysters in harvests], [sic] or on Maryland's prestige and a producer of superior grade oysters. It is a principal in the economy of nature that a species should be reproduced by the best developed and hardiest of its kind. On this principle the progeny of a colony of oysters not yet attained mature development can scarcely be expected to be so vigorous and capable of combatting the many adverse agencies to which these mollusks are subjected to those of a well-stocked reef of large brood oysters." (Stevenson 1894). In short, the act of harvesting living oysters from the public reefs for market and seed uses was also removing (mining) the shell (cultch) needed to sustain the reef habitat and the current and future oyster populations dependent upon it. Eventually, the rate of removal of the living oysters, their shells and, more importantly, their shell-producing capabilities, became greater than the capability of surviving living oysters to replace the plundered, recently produced shell taken with them. To compensate for overharvesting and removal of "fresh" shells, "fossil" shells (themselves remnants of once-productive oyster reefs) have been mined by shell-dredging companies in both states to secure shell for their own purposes and to supply, for a fee, shells for the state oyster repletion programs.

Even as recorded catches decreased and other signs of overharvesting manifested themselves, each state increased activities designed to counter them and preserve the resource and industry. They enlisted the aid of federal fishery and survey agencies. Many facts were discovered and numerous recommendations were advanced. The plethora of restrictive legislation and regulation which resulted (Everstine 1946, Kennedy and Breisch 1983) probably stemmed from a sincere desire of responsible state fishery managers to achieve positive results and equally sincere beliefs that enforcement of those laws and regulations would bring such results about. The same can be said of the efforts of various individuals in each state who promoted repletion programs to rehabilitate dwindling public oyster reefs. Unfortunately, a greater and/or more politically influential number of individuals strove to advance self-interests. Politicians sought votes and oystermen and other industry participants promoted continued, preferably higher, personal incomes. The public's resources and interests suffered.

That the public oyster management effort was failing in Virginia and Maryland and that truly effective countermeasures were required should have been widely recognized and acknowledged well before World War II. But it was not. Annual catches continued to decline, as did the populations whence they were drawn. Oyster reefs were further destroyed in the process.

Science has long recognized that oyster reefs or beds serve as focal points for many estuarine/marine plants and animals of various taxonomic groups and ecological habits. Such aggregations of sessile organisms and their associates serve to attract mobile animals of many species and habits, including grazers and predators such as spot (*Leiostomus xanthurus)*, croaker (*Micropogonias undulatus*) and weakfish or gray trout (*Cynoscion regalis*). They are excellent natural, self-renewing, and self-maintaining fishing reefs. Thus, the Chesapeake's oyster reefs have served both recreational and commercial fishing interests and, if restored or maintained and effectively managed, can do so well into the future. Allowing oyster reefs to be destroyed has further injured the public's ownership rights and interests by reducing these biogeomorphological features and their value as fishing reefs on the public bottoms of the Chesapeake.

Another and perhaps even more important biologically and socioeconomically function of oyster reefs when in their prime was to combine the filtering power of the individual oyster by aggregation into large communal populations. It has been calculated by Hargis and Haven (1988a) that 10,000 adult oysters located in a 50 ft^2 area are capable of filtering 713,390 gallons of water in a 24-hour period. Independently, Newell (1988) found similar high rates of filtration and concluded that the number of oysters existing in the Chesapeake Bay in times before 1870 could potentially filter the entire volume of the Bay in less than three days. He calculated that by 1988 the population had been so diminished that filtering the Bay would require between 244 and 325 days. In times before overuse reduced total numbers of individuals, and the size of their aggregations by destruction of reefs, this filtering capability undoubtedly exerted considerable influence on Chesapeake Bay waters by removing, processing and partially sequestering silt and other particulates from the nearby water during feeding. Ingested material was digested and the unused remainder egested as feces in mucous-bound strings. Rejected material was bound in mucous and ejected as pseudofeces. Much of this material (feces and pseudofeces) contributed food and substrate to bacteria, protozoans, annelids, and many other species, thus enhancing the biota and the food web. This ecologically valuable ability was reduced and the public's ownership rights and ecological interests damaged as overharvesting and concomitant reef destruction were not prevented.

Clearly, these findings of science should be incorporated and applied as the public's interests in restoration of oyster populations and their habitat are being considered. Consequent improvements in finfishing, numbers and diversity of biota, and, probably, a measure of pollution reduction by more effective natural filtration will be additional public "goods" or benefits. Because these functions are interactive, survival of oysters will be enhanced as well.

CONCLUSION

Even now, as Bay-wide public ground oyster harvests have reached their nadir (hopefully), it continues to be difficult, seemingly impossible, to convince many oystermen and some state managers that overharvesting, habitat destruction, and genetic-quality degradation associated with the overharvesting of live oysters and shell (table 1), are the principal long-term causes of the decline of the public oyster resources of the Chesapeake region. The reluctance of oystermen to accept this reality is understandable. Obviously, the incomes of those watermen still dependent in some measure upon oysters from the public reefs are at risk of further reduction if harvesting efforts are restrained or eliminated by restrictive regulations designed to conserve or rebuild stocks or habitat. Closure of the few remaining Chesapeake reefs continuing to produce market-sized oysters would almost eliminate market harvesting in Virginia, however temporarily. The same is true of Maryland. Never mind that continuing declines in the resources will force those same oystermen to seek other resources (assuming that any are left in that finfish, soft clams, hard clams and crabs are also heavily pressured common property resources) or activities to replace the lost income anyhow. To common property harvesters an opportunity to make a catch deferred often means an opportunity lost (Christy 1964). This difficulty was also noted by Stevenson who wrote: "The great trouble with the present methods and regulations is not with the close season or with the implements employed but. . . the oystermen take no individual interest in the preservation and development of the reefs on which they work, their sole object being to obtain at the moment all the oysters possible without reference to the future supply. Individual interests clash with the public good." (Stevenson 1894).

We agree with Stevenson (1894) and Loosanoff (1932) and others who reached the same conclusions. Given the socio-economic realities, an individual fisherman will fish "to the last" with little or no regard to the future of the resource or of his future livelihood, both of which are actually based upon the long-term survival and well-being of that resource. If he doesn't, the "other" harvester will catch what he could have taken for himself. Public oystermen cannot conserve the resource themselves, and they have consistently resisted management controls intended to do so in both states and in the Potomac estuary.

The reluctance of crucial public managers to recognize that harvest-related population reductions, genetic impairments, and habitat (reef) destruction are responsible for the serious depletion of Chesapeake public

oyster resources is much more difficult to rationalize or understand than that of watermen. To be generous, one hopes it has come from a sincere belief on the part of decision makers that the scientific evidence that those phenomena are indeed the cause of the harvest declines is too weak to justify positive action. If so, they are mistaken and have been for some time! In 1932 ,
Dr. Victor Loosanoff, the first marine scientist hired by the Virginia Fisheries Commission, predecessor of VMRC, reported to that body, "The rehabilitation of depleted grounds and the conservation of the James River oyster industry can be accomplished only by adoption of measurescontrolling the harmful effects of overfishing."(Loosanoff 1932) Dr. Loosanoff's advice was not followed. Today less than one-third of the public grounds in the James estuary produce economic quantities of oysters.

Some state managers, even though recognizing that problems exist, have sought to deny that the state management systems are in any way responsible for the long-term decline in oyster populations. They have done so by contending publicly that disease and other factors are primarily to blame (Jensen and Travelstead 1992). Pollution is also regularly invoked by some as a significant contributing cause. Those who blame these factors seem to forget that sound fishery management principles require that allowable harvesting levels of public fishery resources must be related to the actual condition of the stock and its ability to sustain those harvesting levels. Fulfillment of this requirement demands that varying natural stresses such as mortalities owing to disease or predators, poor spatfall, or other "background" causes, including pollution, be factored into establishment of allowable harvest levels. Management agencies that do not actively and honestly attempt to do so can only be considered derelict or incompetent. In truth, biologically justified allowable harvest levels have rarely been established in management of Chesapeake shellfisheries — or even sought.

Data provided above show clearly that disease caused by Dermo and MSX did not cause the long-term, downward trend of market oyster harvests and the populations sustaining them! The decline actually began and gained momentum long before serious mortalities attributable to these diseases were detected in the Chesapeake. Science and state management may have helped reduce the effects of disease and predation by recommending or taking, respectively, various remedial actions, but they have been unable to eliminate them.

But there is reason for hope. Oysters living on their "healthy" oyster reefs survived disease and predation before European settlement, otherwise the reefs and populations they sustained would not have developed, and can do so again provided they are assisted and properly protected. Further evidence of the benefits of upthrusting reefs is provided by scientists of Virginia and Maryland, and others, who have shown that
C.. virginica reared on off-bottom racks or trays can survive to market size in the lower Chesapeake and that they reach adulthood much more rapidly than on the bottom. Hence, we strongly recommend rehabilitation of nature's off-bottom oyster culture systems — the reefs (see below).

Pollution has not been responsible for the long-term decline of public market oyster production in the Chesapeake. We do not contend that toxic pollutants, disease, or predation cannot affect oyster populations. They can and do, but a great portion of the waters around the truly productive public bottoms of the Chesapeake are not toxic to oysters as yet. It is widely known that oysters can survive in some types of non-toxic pollution such as raw and/ or properly-treated poison-free sewage effluents and have done so for decades in the Chesapeake. Of course, using oysters from condemned areas for market purposes requires relaying before sale

Toward a Sustainable Coastal Watershed:
The Chesapeake Experiment. Proceedings of a Conference
1-3 June 1994. Norfolk, VA
Chesapeake Research Consortium Publication No. 149

MARYLAND CHESAPEAKE BAY OYSTER RECOVERY AREAS: SUMMARY OF TECHNICAL INFORMATION

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Abstract: In 1993, the Maryland Oyster Roundtable completed an action plan to restore the ecological and economic benefits of oysters in Chesapeake Bay. A major feature of the plan was designation of six tributaries as oyster recovery areas (ORAs), where intensive management efforts will be made to restore oyster populations. Biological and environmental data were synthesized to support development of management plans for the ORAs. The data are maintained in a GIS data base, and will be updated with monitoring data and management information as the ORA plans are implemented. The ORA tributaries (the Chester, Choptank, Magothy, Nanticoke, Patuxent, and Severn Rivers) have different profiles of hydrography, salinity, and water quality, along with different patterns of oyster recruitment, disease, mortality, harvest, and management history. These differences should influence how the ORAs will be managed. For example, the Nanticoke River contains 58% of the total area of oyster leases within the ORAs, whereas the Chester River has no leased grounds but is now supporting a major portion of the public harvest. The Nanticoke and Patuxent Rivers have steep salinity gradients (because of their high ratios of freshwater discharge to estuarine volume), which could be beneficial in managing around the impacts of oyster parasites. Differences in oyster population structure both within and between the tributaries are symptomatic of disease impacts, and also reflect the effects of recent management history.

INTRODUCTION

The oyster resource in Chesapeake Bay has been severely depleted in the past decade by mortality associated with parasitic infections of *Perkinsus marinus* (Dermo) and *Haplosporidium nelsoni* (MSX). In Maryland, harvests have decreased from > 1,000,000 bushels to < 100,000 bushels in less than 10 years.

In response to this crisis, the Maryland Oyster Roundtable developed an action plan (Tidewater Administration 1993) to established oyster recovery areas (ORAs), Chesapeake Bay tributaries or segments of tributaries that will be managed in innovative ways to support restoration of the ecological and economic benefits of thriving oyster populations. One or more ORAs will be managed primarily to test the hypothesis that a combination of low salinity, isolation from infected stocks, and prohibition of introducing infected seed oysters will result in abatement of *Perkinsus marinus* infection and mortality. Other ORAs will be managed to provide opportunities to prove the economic benefits of private aquaculture, and others as sanctuaries where oyster populations will be given the chance to recover free from both harvest pressure and the possibility of contamination with infected seed transplants. It will be necessary to develop specific plans for the ORAs, each of which may sustain a different mix of management options. This responsibility has been assigned to a subcommmittee of the roundtable.

Six tributaries were designated by the roundtable as ORAs (figure 1). Each of these tributaries has different geomorphic, hydrographic, and biological characteristics, and a different history of how the oyster resource has been managed. A report, *Maryland Chesapeake Bay Oyster Recovery Areas: Summary of Technical Information* (Tidewater Administration 1994) was prepared to bring together relevant information on these tributaries, their suitability for selected management options, and to initiate the process of developing tributary-specific management plans. A synthesis of relevant scientific and technical literature, with emphasis on current knowledge of the epizootiology and ecology of *Perkinsus marinus* and *Haplosporidium nelsoni*, was included. This paper summarizes the specific information about the six tributaries contained in the report, and presents some suggestions about how the information could be used in improving oyster management in Maryland. For background on oyster biology, ecology, diseases, population status, and management, the interested reader is referred to reviews and recent reports by Andrews (1988), Haskin and Andrews (1988), Kennedy and Briesch (1981), Krantz (1990, 1991, 1992), and Smith and Jordan (1993).

Chester River
Choptank River
Magothy River
Nanticoke River
Patuxent River
Severn River

Figure 1. Maryland oyster recovery areas, with oyster recovery zones (see text). The inset shows the tributaries in relation to each other and Chesapeake Bay.

THE OYSTER RECOVERY AREAS

The six ORAs are in estuarine tributaries of Chesapeake Bay formed by drowned river valleys. They receive freshwater discharges from coastal plain streams that drain agricultural, urban, and suburban lands, but vary considerably in morphology, bathymetry, relative contributions of tidal and fluvial waters, salinity gradients, and the characteristics of their oyster resources. Oyster bars charted during the Yates survey of 1906-12 (Yates 1913) are shown in some of the figures. There have been many changes in oyster habitat since the Yates survey, but these charts provide a general picture of potential oyster habitat, and in some cases, approximate recent actual oyster habitat. More recent surveys are being digitized and compared with the Yates data, in part to evaluate long-term changes in oyster habitat. Zones A, B, and C of the ORAs are shown in figure 1; zone boundaries in the Chester and Choptank Rivers were established by the Oyster Roundtable's action plan; all other boundaries are proposed and are shown only for reference. In zones A, all harvest and transplanting of diseased seed oysters will be prohibited. In zones B, harvests will be permitted, but restrictions on seed oysters will be the same as in zones A. No changes in current management or harvest regulations will apply immediately to zones C; however, if success is achieved in restoring oyster populations in zones A and B, all or portions of zones C may become subject to zone B restrictions.

Chester River

The upstream portions of the Chester River and its tributaries drain largely agricultural areas of Delaware and Maryland. It is the northernmost tributary of Chesapeake Bay that is suitable as oyster habitat. The Chester is characterized by a relatively deep channel extending from Chesapeake Bay to Chestertown, with broad shallow flanks in the downstream estuarine reaches.

The lower Chester River is influenced strongly by tidal flows from the Chesapeake. Tidal flows extend upriver to near Millington. Combined discharges from two major tributaries, Morgan Creek and Unicorn Branch, average 35 cubic feet per second (cfs), with combined peak flows ranging up to 194 cfs (June 1972 during Hurricane Agnes). A rough estimate of the drainage basin area suggests that total freshwater flows to the Chester are approximately twice the gauged flows. The broad mouth of the river suggests that winds can exert a strong effect on water levels, wave action, and currents in the lower river.

Seasonally averaged surface salinity near the mouth of the river exceeds 10 ppt only in autumn; salinities are somewhat higher in deeper water (Stroup and Lynn 1963).

The Chester River has experienced some problems with dissolved oxygen, bacterial contamination, and toxic contamination in the past. A severe oyster mortality episode occurred in the Chester in the 1970s. Although water quality problems were implicated in the mortality, the actual cause was never determined (Cooney et al. no date [but about 1980]).

Because of low salinity, Chester River oyster populations have never been known to be infected with MSX disease. In October 1993, Dermo disease was present at high prevalence in the lower river, at slightly lower prevalence farther upstream, and could not be detected in the sample at the most upstream site (figure 2). In 1993, oyster mortality in the lower Chester was 25-50%, symptomatic of the high Dermo prevalence observed. Oyster mortality was low at two sites farther upstream.

The Chester River typically has very low spatfall in many years no spat are found during fall surveys. Significant natural recruitment to the bars in the Chester occurs rarely, and maintenance of harvests in this area has depended largely upon the state repletion program.

The lack of natural recruitment in the Chester is seen clearly in the oyster population profile (figure 2). Note that there are no spat and few small oysters. The source of the large peak of oysters was the 47,000 bushels of seed oysters moved from the lower Bay to Oldfield Bar (CHOF) in the spring of 1992. Many of these oysters were of harvestable size during the 1993-94 harvest season. Buoy Rock Bar in the lower Chester showed the combined impacts of low recruitment and disease mortality, with few live oysters and a high mortality rate.

The Chester River has become a prime area for placement of seed oysters. Because of the low salinity, the oysters are protected from MSX, and only very recently (1992 and 1993) has Dermo been a significant problem in the Chester. Between 1988 and 1992, over 500,000 bushels of seed oysters were planted in the Chester River by the State. All oyster harvest data in this report are compared to a reference year (the 1985-86 season), the last year that Maryland had a harvest > 1,000,000 bushels. That season was just before the major MSX outbreak in 1987, and before the extensive mortalities associated with Dermo disease in the 1990s. Oyster harvests in the Chester River averaged 55,856 bushels from 1990-93 (figure 3). These harvests represent a 262% increase over the reference year. Since 1986, Chester River harvests have increased from 1.4% to 54% of the statewide

Figure 2. Chester River: Historical oyster bars, sampling sites, 1993 oyster population profiles, and Dermo prevalence (percentage of sampled oysters infected with *Perkinsus marinus*). Boxes are dead oysters.

harvest. There has been a trend since 1990 toward increasing harvests in the upper river, although the bulk of harvest remains in the lower and middle portions of the Chester. Shell plantings are not made in the Chester River because of the typically low spat sets. However, shells are incidentally planted in the river as a result of the seed oyster plantings.

There are no leased oyster grounds in the Chester River (leases in the waters of Kent County are prohibited by Maryland law).

Figure 3. Chester River oyster harvests. "Lower," "middle," and "upper" refer to river segments.

Choptank River

The upstream portions of the Choptank River and its tributaries drain largely agricultural areas of Delaware and Maryland. The Choptank is characterized by a relatively deep channel (averaging about 9-10m, but reaching depths of more than 24m near Castle Haven) extending from the Chesapeake Bay to Denton, with broad shallow flanks in the downstream estuarine reaches.

The lower Choptank River is influenced strongly by tidal flows from the Chesapeake. Tidal flows extend upriver to near Greensboro, Maryland. Freshwater discharges to the river at Greensboro average 130 cfs on an annual basis, with peak daily flows ranging up to 829 cfs. These gauge statistics represent about 20% of the total freshwater flows to the river. The broad mouth of the river allows winds to exert a strong effect on water levels, wave action, and currents in the lower river.

The Choptank has a fairly wide range of salinity, and has substantial amounts of oyster habitat in both low and moderate salinity zones (figure 4). Salinity near the mouth of the river averages 10-14 ppt depending on season (Stroup and Lynn 1963), and has reached at least 18 ppt in some years.

Figure 4. Salinity of the Choptank River (summer 1993 averages).

The Choptank River has experienced few problems with dissolved oxygen and toxic contamination. Bacterial contamination associated with municipal sewage effluents and combined sewer overflows at Cambridge have caused local problems.

Choptank River oyster populations have been severely affected by diseases in the past several years. The Choptank was virtually free of MSX until 1982; in 1987, the disease caused major mortalities in the lower river. In 1992, MSX was found at all survey sites in the Choptank. Dermo disease has been increasing in prevalence, intensity, and upstream extent in recent years. By 1992, all survey sites were infected, with prevalence approaching 100%. This high rate of infection was sustained in 1993 (figure 5). Dermo infection was detected at a supplementary upstream site sampled in 1993 (figure 5; CRCA), but with very low prevalence. This site was not sampled in 1992.

Oyster mortality in the lower Choptank has been high since 1987, and excessive mortality has moved upstream with the spread of disease. Populations in the lower salinity reaches of the river have experienced lower mortality, but are now showing the effects of continued Dermo infections.

Historically, spatfall has varied widely in the Choptank system. Areas such as Broad Creek typically have very high sets, and others, particularly the low-salinity, upstream areas, rarely receive good sets. Spatfall was excellent in the lower Choptank in 1991, but poor in 1992 and 1993. Until recent years, natural recruitment was capable of sustaining large oyster populations and substantial harvests in much of the Choptank. In the late 1980s and the 1990s, however, populations have been depleted by disease, and only the upstream reaches of the river (above Cambridge) have supported harvests. In 1993, mortality (owing primarily to Dermo disease), is seen in the box counts, with peak abundance at about 60 mm (figure 5). Many of the larger live oysters in the population profile probably were transplants placed in the upper river during 1991 and 1992; Oyster Shell Point Bar (figure 5: CROS) received 45,000 bushels of seed oysters over the two-year period.

Large amounts of dredged shell and considerably smaller amounts of fresh shell, a total of 3.9 million bushels, were placed on 629 acres in the Choptank River and its tributaries between 1988 and 1992. Shell repletion was applied both to seed areas, such as Broad Creek, and for rehabilitation of natural oyster bars. Much of this shell was

Figure 5. Choptank River: Historical oyster bars, sampling sites, 1993 population profile, and Dermo prevalence (percentage of sampled oysters infected with *Perkinsus marinus*). Boxes are dead oysters.

planted in 1988 and 1989 in areas of the lower river that are now not productive, either of harvestable oysters or seed oysters. These large shell plantings, however, may remain as a resource for maintaining the recruitment potential of oyster populations in the lower Choptank. Over 800,000 bushels of seed oysters were planted on 1,548 acres in the Choptank River and tributaries between 1988 and 1992. Some of these seed oysters originated from seed areas within the Choptank system. In recent years, transplants in the upper estuary (above Cambridge) have supplied much of the Choptank oyster fishery.

Through the 1980s, the Choptank was one of the most productive areas for the oyster fishery in Maryland. Much of this fishery depended on natural (not transplanted) stocks. Oyster harvests in the Choptank River have declined severely over the past several years (figure 6). The 1993 harvest was only 3.5% of the harvest in 1986, the reference year. In the 1980s and early 1990s, the Choptank supported a large percentage of the statewide harvest (26% in 1986 and 55% in 1992). By 1993, after Dermo had infected virtually all of the Choptank stocks, only 14% of the statewide harvest came from this tributary; virtually none came from the extensive areas of formerly productive oyster bottom in the lower river.

There are 488.5 acres of leased oyster grounds in the Choptank River system (figure 7); most of the leased grounds are in the tributaries. Only about 10 acres are leased in the Choptank River proper. There has been no reported production from these leases in recent years.

Figure 6. Choptank River oyster harvests. "Lower," "middle," and "upper" refer to river segments.

Figure 7. Acreage of leased oyster grounds in the ORA tributaries.

Magothy and Severn Rivers

The Magothy and Severn Rivers are discussed together because of their relatively small size, proximity, general similarity, and lack of data. Both rivers drain mostly urban and suburban areas of Anne Arundel County. They are relatively small coastal plain rivers, with well-developed estuaries in their lower reaches. They differ from the Eastern Shore tributaries in having narrow valleys lined with steep, eroding bluffs. Both of these rivers have deep central channels and generally lack the large areas of shallow water necessary for development of extensive oyster bars (especially the Severn). The lower Severn and Magothy Rivers are influenced strongly by tidal flows from the Chesapeake. Freshwater discharge data are not available.

Tidal flows from the Chesapeake maintain saline conditions suitable for oyster survival throughout most of the estuarine reaches of these tributaries, typically 5-10 ppt (figure 8).

The Severn and Magothy Rivers have experienced chronic problems with low dissolved oxygen in summer. Bacterial contamination associated with urban point and nonpoint source discharges also has degraded the water quality of these rivers.

There are no disease sampling sites in these tributaries at present. Very limited historical data may be available, but have not yet been summarized. There are no established oyster monitoring stations in either of the two rivers. Some population and spatfall data are available from the traditional fall survey, but these data have not yet

Figure 8. Salinity of the Magothy and Severn Rivers (summer averages 1989-92).

been summarized. Both systems were severely affected by the freshet associated with Hurricane Agnes in 1972 and extreme Bay ice conditions in 1977-78 (Krantz 1977); since then only remnant oyster populations have remained in these tributaries.

No shell plantings were made by the state in the Severn or Magothy Rivers from 1988 through 1992. One acre was planted with 1,010 bushels of seed in the Severn River in 1992. This was the only documented state repletion effort in these tributaries in recent years. There have been no reported public oyster harvests in the Severn or Magothy Rivers in recent years (1986-93). There are 168 acres of leased oyster bottom in the Severn River, and 109 acres in the Magothy River (figure 8). Oysters have been harvested from some of the Magothy River leases in recent years.

Nanticoke River

"Flowing through the Embayed Coastal Section of the Atlantic Coastal plain, the Nanticoke River gathers its waters from the swamps and cultivated flatlands of Sussex County, Delaware and cuts across Maryland's lower Eastern Shore" (Maryland Department of Natural Resources 1986). Predominant land uses are agriculture and wetlands, both tidal and nontidal. Although there are several small cities and towns in the watershed, the Nanticoke is one of the least-developed watersheds in coastal Maryland. Unlike the other tributaries described here, the Nanticoke does not flow directly into Chesapeake Bay, but joins the northern end of Tangier Sound.

Combined freshwater discharges from the Nanticoke at Bridgeville, Delaware, and the Marshyhope at Adamsville, Delaware, average 143 cfs on an annual basis. Combined peak monthly average flow at these two gauges was 752 cfs, with daily peaks exceeding 3,000 cfs. These flows probably represent less than 50% of total freshwater flow to the river. The ratio of freshwater flow to estuarine volume in the Nanticoke apparently is high; this factor, combined with the relatively high salinity at the mouth of the river, suggests that oyster growing areas in the Nanticoke experience wide fluctuations in salinity. Salinity data from summer 1993 are shown in figure 9.

Although the watershed is less developed than the others discussed here, there have been some concerns in recent years about possible water quality problems in the Nanticoke River. The river receives municipal, industrial, and agricultural discharges. Upper tidal reaches of the river in Delaware have been closed to shellfish harvesting in recent years.

Figure 9. Salinity of the Nanticoke River (summer 1993 averages).

One site in the Nanticoke River, Wilson Shoal Bar, has been monitored consistently for oyster diseases since 1990. In 1992, oysters at this site were heavily infected with both Dermo and MSX. In 1993, this site had no detectable MSX, but Dermo persisted at high prevalence (figure 10; NRWS). During the 1993 survey, a supplementary sample was analyzed from Wetipiquin Bar (the upstream bar NRWE, in figure 10) for Dermo; prevalence was 87%, with moderate intensity of infection. In 1993, oyster mortality in the lower Nanticoke was about 25%, symptomatic of the high Dermo prevalence observed. The upstream site had low mortality. Mortality appeared to be somewhat lower than in 1992, presumably because MSX had disappeared by the fall of 1993.

Spatfall in the upper and middle Nanticoke in recent years has been low (<5 0 spat per bushel 1990-93). A site near the mouth of the river has had low to moderate spatfall (107 spat per bushel in 1991). Some spat were present at all three sites in 1993 (figure 10).

Oyster population structure in the Nanticoke varies predictably from upstream to downstream.

Figure 10. Nanticoke River: Historical oyster bars, sampling sites, 1993 oyster population profiles, and Dermo prevalence (percentage of sampled oysters infected with *Perkinsus marinus*). Boxes are dead oysters.

At the upstream site, small oysters were fairly abundant in 1992, with some market oysters present, but very few spat. Higher numbers of spat were found at the more downstream sites, but mortality had taken a heavy toll on earlier year classes; live small and market oysters were few, and heavy mortality was evident in box counts. The pattern was very simlar in 1993, but, some of the abundant 1991 year class oysters were entering the fishery (76.2mm), and mortality was somewhat lower (figure 10).

From 1988 to 1992, only a few small plantings of fresh shell were done by the state in the Nanticoke. The state planted 117 acres of oyster bars in the Nanticoke River with approximately 86,000 bushels of seed oysters between 1988 and 1992.

Oyster harvests in the Nanticoke River averaged 6,549 bushels between 1990 and 1993. Over 21,000 bushels were harvested in 1986, the reference year (figure 11). The Nanticoke contributed 1.4% of the statewide harvest in 1986, and 7.7% (estimated) in 1993.

There are 2,209 acres of leased oyster bottom in the Nanticoke River (figure 7). This is the largest area of leases of all of the ORA tributaries (58% of the total area of leased grounds in the ORA

Figure 11. Nanticoke River oyster harvests.

tributaries). Some Nanticoke River leaseholders have harvested oysters from their grounds in recent years.

Patuxent River

The Patuxent River drains Piedmont and coastal plain areas encompassing about 10% of the total land area of Maryland. The estuarine reaches of the Patuxent are narrow (compared to most other Chesapeake tributaries) and in some reaches enclosed by high banks. The Patuxent watershed has been undergoing rapid urbanization over the past three decades, with concomitant loss of agricultural, forested, and wetland land uses.

The Patuxent is the deepest of Maryland's Chesapeake tributaries, reaching depths of about 40 m, but has sufficient shallow areas to support a large amount of oyster habitat. The narrow morphology of the Patuxent results in strong tidal flows, which extend for over 72 km upriver from the mouth. Freshwater discharge from the upper Patuxent near Bowie averages 355 cfs on an annual basis, with peak daily flows up to 8,860 cfs. Peak instantaneous flow, during Hurricane Agnes in June 1972, exceeded 31,000 cfs. Gauged flows near Bowie represent about 25-30% of total freshwater flow to the river. Like the Nanticoke River, the Patuxent has a high flow-to-olume ratio, suggesting the potential for wide salinity fluctuations in oyster habitat areas. The tidal Patuxent has a wide range of salinity, from fresh water to peak salinity of 20 ppt or more at the mouth; average surface salinity at the mouth varies seasonally from about 11 ppt to16 ppt (Stroup and Lynn 1963). Salinity data from the summer of 1993 are shown in figure 12. There is a substantial amount of oyster habitat in the 5 ppt-10 ppt salinity zone.

One site in the Patuxent River has been monitored for oyster diseases in recent years. In 1992, oysters at this site were infected with both Dermo and MSX. In 1993, Dermo prevalence was 87%; MSX was not detectable in the fall survey sample (figure 13). In 1992, oyster mortality in the Patuxent was greater than 50% at the two sites monitored, reflecting the presence of both MSX and Dermo diseases. Mortality steadily increased from 1990 to 1992, resulting in loss of virtually all harvestable oyster stocks in the river. Despite the apparent absence of MSX in 1993, there still were few live oysters, and there was evidence of continuing high mortality (figure 13).

Spatfall was low (<50 spat per bushel) in the Patuxent from 1990-1992. No spat were observed in the 1993 fall survey (figure 13). Oyster population structure in the Patuxent is representative of oyster stocks that have been devastated by diseases (figure 13). Population profiles from 1991, 1992, and 1993 showed more boxes than live oysters in nearly all size classes. Mortality was much less apparent in 1990 population profiles.

About 37,000 bushels of fresh shell were planted on 22 acres in the Patuxent by the state between 1988 and 1992. No dredged shells were planted during this period. About 164,000 bushels of seed oysters were planted on 203 acres in the Patuxent between 1988 and 1992. Patuxent River oyster harvests have declined from 96,342 bushels in 1986 to no recorded harvest in 1993 (figure 14). This complete collapse of the fishery has been closely associated with the spread of Dermo disease in the river.

There are 807 acres of leased oyster grounds in the Patuxent River system (figure 7). The leased bottom represents 21% of the total leased area within the ORA tributaries.

DISCUSSION

The principal reason for establishing ORAs in Maryland is to at least partially restore dwindling oyster populations for both ecological and economic benefits, despite chronic problems with parasitic diseases. Low salinity, isolation of oyster populations from heavily infected stocks, protection of natural adult brood stocks, and enhanced recruitment are thought to provide the best opportunities for achieving positive results.

Suitable salinites are found in all of the ORA tributaries. A problem common to all, however, is that salinities that provide protection from the parasites (< 10 ppt) are for the most part not conducive to reliable

Figure 12. Salinity of the Patuxent River (1993 summer averages).

natural reproductive success (39 ppt). Tributaries such as the Patuxent and Nanticoke Rivers, with wide and highly variable salinity gradients may offer the best opportunites for natural recuitment in areas where oysters can survive to harvestable size.

Zones A and B of the ORAs are intended to isolate oyster populations from further introductions of infected oysters. The primary concern is *Perkinsus marinus,* known to be spread contagiously by proximity to infected oysters (Andrews 1988). *Perkinsus marinus* also has been identified from open waters (Roberson et al. 1993); how far infectious pressure can spread by this route is not known. Andrews (1988) recommended managing Dermo disease essentially by dilution, which can be accomplished by avoiding introductions of infected oysters, enhancing populations only with uninfected seed oysters or natural recruitment, and removing infected stocks from the area. Isolation may be best demonstrated in the Severn and Magothy Rivers, which have not received significant plantings of infected oysters. Existing natural oyster populations in these tributaries are remnants at best, and therefore, parasite populations also should be low or absent.

A part of the rationale for closing zone A areas to harvest is to protect brood stocks to ensure and enhance natural recruitment. Because all of the proposed zone A areas are in very low salinity reaches, this strategy will depend on two kinds of dynamics. First, in order to support historical oyster populations, these areas must have received reasonable natural sets of young oysters occasionally (although these events may have been a decade or more apart, in years of extremely high summer salinities). Second, oysters may produce viable eggs and sperm even in very low salinities. If the larvae are transported downstream by ebb tides after spawning and fertilization, they may remain competent to set and maintain or enhance downstream populations. The Choptank River is an example of a tributary that has still has fairly abundant oyster populations in zone A.

Figure 13. Patuxent River: Historical oyster bars, sampling sites, 1993 oyster population profiles, and Dermo prevalence (percentage of sampled oysters infected with *Perkinsus marinus*). Boxes are dead oysters.

Figure 14. Patuxent River oyster harvests. "Lower," "middle," and "upper" refer to river segments.

In addition to the need for sufficient brood stocks, enhancing recruitment will require the presence of sufficient good quality habitat for settlement, survival, and growth. Several habitat improvement methods have been suggested, including cultivation of the bottom to bring buried oyster shell to the sediment surface and to wash sediment from shells, placement of artificial materials such as concrete to stabilize the bottom, and increased use of natural materials such as dredged shells for cultch. Artificial reef structures may be used to provide substrate for development of oyster reef communities, principally for their ecological benefits. The loss of great numbers of oysters to Dermo and MSX in the past 3 years must have left substantial shell resources in the ORA tributaries, especially in the lower Choptank and Patuxent Rivers. Perhaps these shells have not yet been buried so deeply that they cannot be recovered without the use of heavy dredging equipment, and therefore could provide an economical source of material for bottom rehabilitation.

Monitoring of oyster populations, recruitment, diseases, and management activities will be essential to evaluating these new directions, and in maintaining accountability for adherence to the new policies established by the action plan. Substantial improvements have been made to Maryland's traditional oyster monitoring program since 1989 (Smith and Jordan 1993), and additional improvements are being designed to serve data needs created by the action plan. Much emphasis has been put on careful and responsive data management. Oyster monitoring data are maintained on a geographic information system (GIS) that allows integration of maps, statistical graphics, data tables and text (see figures). The GIS also will facilitate maintaining accurate information on the locations of sampling sites, zone boundaries, and management and research activities. Another important technical responsibility will be to ensure that only seed oysters of acceptable quality are planted in zones A and B of theORAs. A program to provide diagnostic screening and formal approval of seed oysters is being developed at the Cooperative Oxford Laboratory.

The Maryland Oyster Roundtable's action plan presents an excellent opportunity for policy, management, science, and private interests to work together for the benefit of a valuable natural resource. A reliable common source of technical information will be a key element in implementing the oyster recovery. We are committed to sound collection and maintainence of the necessary physical and biological data, and also to synthesizing and disseminating information as it is needed.

ACKNOWLEDGEMENTS

Lease data were provided by Jerry Tolodziecki, and hydrologic data were provided by the U.S. Geological Survey. Kelly Greenhawk prepared the graphics. Mark Homer, Paul Massicot, Roger Newell, and Gary Smith commented on the parent document. This paper was supported in part by grants from the National Oceanic and Atmospheric Administration (NOAA). The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies.

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Toward a Sustainable Coastal Watershed:
The Chesapeake Experiment. Proceedings of a Conference
1-3 June 1994. Norfolk, VA
Chesapeake Research Consortium Publication No. 149

THE EFFECTS OF THE 1993 FRESHET ON CHESAPEAKE BAY OYSTER POPULATIONS

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Abstract: In 1993, record streamflows for April in the Potomac and Susquehanna Rivers produced the largest freshet to inundate Chesapeake Bay since Tropical Storm Agnes. Consequently, an extended period of depressed salinities resulted in oyster mortalities of between 57% and 91% on the upper bars of the Potomac River and a tributary, the Wicomico River. Losses in the upper Chesapeake Bay were from 12% to 16%, while the Chester and Choptank Rivers were unaffected. Mortalities on Potomac River bars increased downriver to Lower Cedar Point, then decreased, suggesting that oysters on the uppermost bars were better adapted to low-salinity conditions. Ninety-eight percent of the market oysters on Lower Cedar Point perished in the freshet. On bars with heavy losses, death rates appeared to be size-specific, with market oyster (shell height ž 76 mm) mortalities consistently higher than mortalities for small oysters (height < 76 mm). A follow-up survey five months later yielded much lower mortality estimates, suggesting that empty, articulated oyster valves begin to separate within a few months of death. Owing to increasing disease pressure, these marginal salinity regions support the remnants of Maryland's commercial oyster production; a massive freshwater kill could be disastrous. For example, the 1993 freshet has devastated the remaining Potomac River fishery. New management initiatives involving oyster rehabilitation projects in these low-disease, low-salinity areas need to be approached with caution.

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Chesapeake Research Consortium Publication No. 149

Economic Aspects of the Chesapeake Bay Oyster Fishery: Problems and the Future or Should the Industry be Revitalized?

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Abstract: Between 1930 and 1939, average annual landings of *Crassostrea virginica* from Chesapeake Bay was 32 million pounds (meat weight). During the period 1980-88, average annual landings declined to 14.6 million pounds. In 1990, landings declined to less than 3 million pounds of meats. It has been this consistent downward trend in landings, particularly since 1983, that has concerned that National Marine Fisheries Service, various state agencies, and members of the oyster industry. In response to declining harvests, the National Oceanic Atmospheric Administration Sea Grant Program in cooperation with the National Marine Fisheries Service and various state agencies and sea grant programs developed *A Plan Addressing the Restoration of the American Oyster Industry*. The plan recommends that roughly $3 million annually allocated between 1991 and 1995 for research dedicated to restoring the oyster industry. A proposed $15 million budget raises two important issues that must be addressed: (1) should the industry be revitalized, and (2) if so, what needs to be done. In this paper, we offer that revitalization depends upon the marketability of oysters. A nationwide survey of wholesalers conducted in 1992 suggests that consumer demand for oysters has dramatically declined. Alternatively, oysters may be nearing the end of their product life cycle or going the way of the Edsel, IBM personal computer, or Yugo. Industry revitalization efforts, therefore, must be closely linked to, at least, a generic marketing campaign directed at restoring consumer confidence in oyster products. We conclude, however, that resource enhancement efforts based on bio-remediation goals (enhancing water quality and decreasing the population of jellyfish) may be warranted, and enhancement activities rather than industry revitalization efforts should be the focus of a national research program.

INTRODUCTION AND DISCUSSION

Industry Problems and the Need for Public Assistance

Over the past 60 years, landings of the eastern oyster, *Crassostrea virginica*, from the Chesapeake Bay region have precipitously declined (figure 1). This decline has been particularly pronounced, however, since the second half of the1970s, when landings exceeded 20 million pounds of meats per year. Since 1990, landings have been less than 4 million pounds of meats per year. In response to the rapid and large decline in landings, the National Oceanic Atmospheric Administration (NOAA), Sea Grant Program, National Marine Fisheries Service(NMFS), National Coastal Resources Research and Development Institute, and various state agencies and sea grant programs developed a strategic plan for restoring the American oyster industry (Virginia Sea Grant 1990).

The plan outlines numerous major program areas and objectives for industry restoration. More important, however, is that the plan recommends annual expenditures of approximately $3, million per year between 1990 and 1995 or a total $15 million for industry restoration activities. Given that the entire exvessel value of landings from the region is less than $15 million per year, the decision to allocate

$3 million for oyster industry restoration activities needs to be carefully scrutinized. Alternatively, are there problems affecting the industry other than raw material supply that need to be resolved in order to successfully restore the industry?

In this paper, we address the question of whether or not $15 million should be allocated to industry restoration activities. A more detailed analysis of the oyster industry and associated restoration activities is provided in Lipton and Kirkley (1994). We focus on problems identified by fishermen, processors, wholesalers, and dealers, and consumer demand for oysters. Results of a nationwide survey of dealers and an analysis of consumer demand for oysters suggest that there has been a large change in the demand for oysters; since 1982, the per capita demand for oysters has declined by 54% and total demand has declined 52%. We conclude that oysters as a consumer product are going the way of the Edsel, Yugo, and IBM personal computer / oysters appear to be near the end of their product life cycle. We also, however, offer two positive notes:

1. The decline is not irreversible; a well-structured marketing effort could restore consumer confidence in the product.
2. Recovery of the resource for the purpose of bioremediation may offer substantial economic benefits to society.

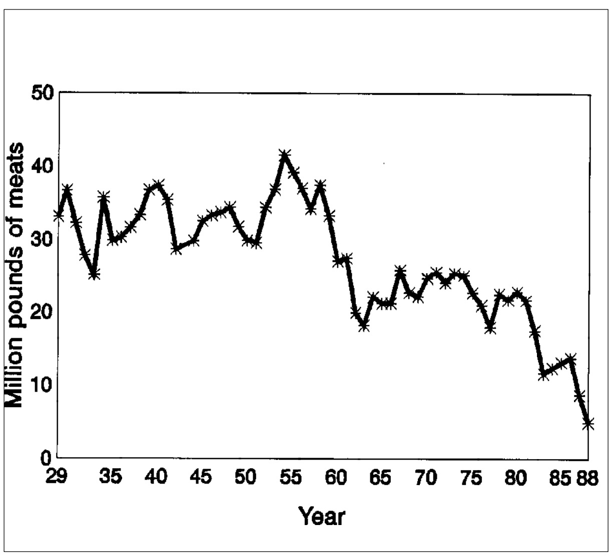

Figure 1. Annual landings of *Crassostera Viginica* from Chesapeake Bay region, 1929 - 1988.

Resource and Economic Conditions and Restoration Activities

What the Fisher Thinks

A survey of Maryland and Virginia fishers provided rather significant conclusions about resource conditions and possible restoration policies. Not surprising, a majority of fishers (60%) did not believe that overfishing was responsible for declining resource levels (table 1). A majority (65%) suggested that disease was primarily responsible for declines in the resource level of *Crassostrea virginica;* 39% of the respondents thought water pollution was the primary reason for reduced resource conditions. An overwhelming 79% of the respondents believed that consumer concern about product safety was seriously hurting the U.S. oyster industry.

What options for improving resource levels were supported by fishers? Nearly 80% of the respondents stated they supported increased seeding. Eighty-one percent stated they thought increased shelling would improve resource conditions. Use of disease-resistant native oysters was supported by 54% of the respondents, and 47% of the respondents thought that fast-growing cultured oysters should be used to restore resource levels.

When asked about the introduction of the Japanese oyster, *Crassostrea gigas*, there was a clear difference of opinion between Maryland and Virginia fishers. Nearly 90% of the Maryland harvesters indicated they did not support introduction of the Japanese oyster. In comparison, 83% of the Virginia fishers supported introducing *gigas*. A large majority (71%) of the Maryland fishers also indicated that they thought the introduction of *gigas* was very risky, while only 34% of the Virginia fishers thought the introduction of the Japanese oyster was risky.

What the Processor/Dealer Thinks

An initial limited survey of dealers in the Northeast revealed that dealers and processors had been negatively affected by the decline in the industry. Approximately 51% of respondents indicated they had laid off employees because of declining resource conditions. Eighteen percent of the respondents, however, stated they had actually increased the number of employees.

When asked about obtaining supplies of oysters to fill orders, only 37% of the respondents indicated they had a problem. Moreover, many processors stated that when they had supply problems, the purchased eastern oysters, *Crassostrea virginica*, from Gulf state dealers. Last, 73% of the Northeast respondents stated that in their view the future prospects for the oyster industry were bad.

Marketing Issues: Demand, Status, and Problems

To better understand the problems facing the industry, a detailed survey of 863 dealers in the United States was conducted in 1992. An overwhelming 85% of the respondents indicated that negative media publicity was the number one problem confronting the industry (table 2). However, only 60% and 69% of the respondents from Maryland and Massachusetts respectively indicated that negative media publicity was the major problem. Consumer concerns about product contamination and water quality were identified as the second major problem facing the industry. Only 47% of the Virginia dealers thought consumer concern about product contamination was a major problem.

A major survey question with significant ramifications for industry restoration activities was whether dealers thought supplies were inadequate. Only 19% of the respondents indicated they thought supplies were inadequate; 31% and 47% of the Maryland and Virginia dealers respectively, thought supplies were inadequate. In comparison, only 4% of the dealers from Washington State, which has a large aquaculture industry, stated that supplies were inadequate.

Another problem identified by analysis of the survey results was consumer resistance because of health / nutritional concerns. Thirty-seven percent of the respondents said that consumer resistance posed a major problem; these were primarily dealers in Alabama, Delaware, Florida, Hawaii, New Jersey, Oregon, Pennsylvania, Texas, and Washington State. Only 23%and 20% of the Maryland and Virginia dealers, respectively thought consumer resistance posed a major problem.

When asked about price levels, only 18 % and 20% of respondents thought wholesale and retail prices respectively, were too high. One hundred percent of the respondents from Washington, D.C., indicated that retail and wholesale prices were too high; 43% of the New York dealers thought retail prices were too high. Thirty-eight percent and 46% of Maryland dealers thought retail and wholesale prices were too high. Similarly, 40 % and 47% of the Virginia dealers thought retail and wholesale prices were too high.

Regarding competition from foreign imports, only 18% of the respondents thought that imports posed a problem for the oyster industry. Most of the respondents that indicated they thought imports were a problem were from Louisiana. For unknown reasons, 37% of the Maryland dealers and only 7% of the Virginia dealers thought that imports posed a problem.

Another important finding of the survey was dealer preferences for type and species of oyster. Whether or not dealers and consumers have preferences for a particular species or differentiated product has important ramifications for industry restoration activities. For example, if resource levels of the eastern oyster in the Chesapeake Bay region were restored but there was a clear preference for oysters from other areas or for different types of oysters, industry restoration efforts would fail without an appropriate marketing campaign. Overall, 68% of the respondents indicated they had a brand name preference, and 40% stated they preferred local to regional oysters; only 12% of the respondents indicated they had a species preference. Eighty-four percent of the respondents stated they preferred oysters from a specific state while 56% indicated they preferred that their oysters come from a particular body of water.

Responses to a question on seasonality provided unexpected results. While the respondents indicated a clear pattern in seasonal demand, 59% of the respondents said their sales did not follow seasonal patterns. In fact, they sold oysters year-round. States in which dealers indicated substantial nonseasonal sales included California, Florida, Massachusetts, New York, and Pennsylvania. Dealers from the other states indicated that sales were definitely seasonal.

What about the half-shell trade? The half-shell trade has traditionally been the product yielding the highest return. Overall, 43% of the dealers indicated they preferred the oyster, *Crassostrea virginica*, from the Eastern states; only 14% of the dealers indicated they preferred *virginica* from the Gulf states. Dealers from Hawaii and Washington State were the only ones indicating a preference for *gigas* for the half-shell trade.

Responses to a question about dealers' species preferences for the shucked-meat trade indicated that preferences were likely to be regional-specific. For example, 37% of the dealers indicated they preferred eastern *virginica* while 21% preferred Gulf coast *virginica*. Dealers preferring the eastern source were primarily from East Coast states while dealers preferring Gulf coast *virginica* were

Table 1. Attitudes of East Coast oyster fishers about the oyster industry.

Table 2. Ranking by firms of one of four major problems.

Problems 1-12: (1) high retail price, (2) consumer concerns about production contamination/water quality, (3) consumer resistance health/nutritional concerns, (4) familiarity with oysters, (5) negative media, (7) high wholesale prices, (8) price competition with other types of oysters, (9) inadequate state/ federal regulations, (10) competition with imports, (11) other, (12) have no opinion.

located in Gulf states. Similarly, dealers indicating a preference for *gigas* or the Japanese oyster were located on the West Coast of the United States.

Last, 5% of the dealers indicated they were not going to sell oysters of any type in 1993. Five percent stated they may not sell oysters in 1993 , and 4% indicated they were uncertain about selling oysters in 1993 or any other year. The majority of the respondents indicated that they either would not sell or may not sell oysters in 1993 were from Louisiana and Texas.

What the Consumer Thinks

Given a limited budget, we were unable to actually survey the consumer. Data on at-home and away-from-home consumption, however, were available from the USDA National Food Consumption Survey and the NMFS National Seafood Consumption Survey. These data were used to assess the at-home and away-from-home demand for oysters.

At-Home Demand for Oysters

The demand for at-home consumption was examined for three product forms: (1) fresh / frozen oysters, (2) canned oysters, and (3) oyster stew. Details of the analytical methodology are available in Berry (1992), Buss (1990), Buss and

Strand (1991), and Lipton and Kirkley (1994). Analyses indicated that different factors influence consumer demand for each product.

As one might expect, household income positively affected the likelihood of fresh and canned oyster purchases (table 3). Income, however, had a negative influence on the demand for oyster stew. In comparison, household size had a negative influence on purchasing fresh and canned oysters but positively influenced purchases of oyster stew. The analysis also revealed that families with children were less likely to purchase any product form of oysters. The age of the homemaker was also found to be an important determinant of oyster sales; a homemaker more than 44 years of age was found to be twice as likely to purchase oysters as a younger homemaker. Households with a male head of household were more likely to purchase all types of oysters than were households with a female head of household. Nonwhite households were also found to be more likely to purchase fresh and canned oysters but less likely to purchase oyster stew.

The tradition of purchasing oysters in "R" months was also found to be supported by the analysis. The positive influence of "R" months, however, was restricted to purchases of fresh oysters. The influence of "R" months was not found to characterize purchases of either canned oysters or oyster stew. This result coincides with dealer and processor responses that oyster sales are not really seasonal. There was, however, evidence that households are more likely to purchase canned oysters and oyster stews during the fourth quarter.

Away from Home Demand for Oysters

Data necessary for a detailed analysis of the away-from-home demand were not available. Rather than ignore this important source of consumption, the number of times a household head purchased oysters away from home in a month was analyzed (for additional information on the methodology, see Berry 1992, Buss 1990, Buss and Strand 1991, Lipton and Kirkley 1994). The number of times a household purchased oysters was examined relative to certain household and market characteristics.

Factors found to have a positive influence on the number of times a household purchased oysters in a month were household income, rural residence, suburban residence, and sex (table 4). The following factors were determined to have a negative influence on the number of times a household purchased oysters in a month: education (more educated less likely to purchased oysters away from home), New England resident (individuals from New England less likely to purchase oysters away from home), New York Metropolitan area resident, mid-Atlantic resident, and retail price. Retail price, however, only had a negative influence during the off-season or non "R" months.

$15 million and Should the Industry Be Revitalized

Whether or not $15 million should be allocated to restoring the industry is a question that has already been answered. NOAA / NMFS has regularly funded oyster research since 1990. Moreover, the political process has determined that industry restoration is a priority of the research dollars. Given that oyster industry restoration is a research priority of the federal and state government agencies, what needs to be done other than increasing the available resource?

Research presented in this paper demonstrates that successful restoration of the industry will require a major marketing campaign. The demand for oysters has substantially declined over the past 10 years; the market demand is simply very weak. Consumers are concerned about product quality, safety, and water quality.

A successful marketing campaign will have to address consumer confidence and concerns about product safety and water quality. Individuals younger than 40-45 years of age will have to be targeted; older individuals are familiar with oysters. New products will have to be introduced to the consumer. Consumption of raw oysters, once the major product of the industry relative to income opportunities, will continue to be highly discouraged.

If a marketing campaign is to be supported by public funds, it will be necessary to develop a national, regional, and local marketing strategy. A comprehensive strategy is necessary to ensure equity among the nation's oyster harvesters and processors. If a program was implemented today and was successful in increasing the demand for oysters in a year, Gulf Coast and West Coast dealers would benefit; fishers and dealers in the Chesapeake Bay area would not have sufficient natural resource levels to supply

Table 3. Factors influencing the at home demand for oysters.

[a]++ indicates sigificant and positive influence on oyster demand at 10% or less level of statistical significance.
[b]NS indicates variable does not significantly influence oyster demand.
[c]–indicates significant and negative influence on oyster demand at 10% or less level of statistical significance.

Table 4. Factors influencing away from home demand for oysters.

[a]Compared with residence in south.
[b]Only significant during months for which spelling does not contain the letter "R".

the market. Alternatively, importers may reap the benefits of a successful marketing campaign.

Even if industry restoration activities are not supported by economic analysis, there may be substantial reasons for restoring the resource. Bioremediation has often been suggested by researchers as a product of resource restoration. That is, it is hypothesized that more abundant resource stocks would improve water quality and reduce the population of jellyfish in the Chesapeake Bay. If true, the economic benefits would be substantial. There would be increased demand for boating, swimming, and fishing, and property values would likely increase. It is possible that the recreational benefits from improved water quality and reduced jelly- fish populations would far exceed the benefits possible from industry restoration.

CONCLUSION

Fifteen million dollars or $3 million per year for five years is a lot of money to devote to restoring the oyster industry. Analyses of market conditions clearly indicate that the oyster industry is in a state of decline. The decline, while possibly or partially related to resource conditions, is very definitely related to declining consumer demand. Supplies and prices have both dramatically declined, particularly since l990; the simultaneous decline in prices and supplies is a clear indication of declining consumer demand. Shifts in consumer demand for oysters appear to have been caused by negative media publicity, consumer concerns about health and nutrition, product safety, and water quality.

Because policy makers have decided to focus on restoring the industry, it is necessary to develop policies that will enhance market demand and resource levels. Increasing resource abundance of *Crassostrea virginica* in the Chesapeake Bay region is only one major priority. It will also be necessary to develop a major marketing campaign a campaign that must be cognizant of geographical differences. The successful campaign will have to mitigate the influence of negative media publicity, promote new products, target individuals that are not familiar with oysters, and eliminate the negative influences of a "health-conscious" America.

Moreover, if the industry of the northeastern United States is to be restored, it will be necessary for dealers in these states to reestablish markets lost to other producing regions and species. The Chesapeake Bay area producers will also have to focus on convincing potential consumers that water quality and pollution are not problems. Producers will also have to develop cost-saving processing and harvesting techniques in order to be competitive with Gulf Coast and West Coast producers. New products or value-added product lines will have to be developed.

Last, even if economic conditions do not warrant industry restoration activities, there may be reasons for restoring resource abundance. The most important possible reason may be bioremediation or cleaning up the Chesapeake Bay and its tributaries. If increased populations of oysters actually improve water quality and decrease the population of jellyfish, the economic benefits of bioremediation may be quite substantial. In fact, the economic benefits of bioremediation may far exceed the benefits of restoring the oyster industry.

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Toward a Sustainable Coastal Watershed:
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1-3 June 1994. Norfolk, VA
Chesapeake Research Consortium Publication No. 149

Protein, Carhohydrate, and Lipid Levels Associated with Metamorphic Success in Larvae of the Eastern Oyster, *Crassostrea virginica*

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Abstract: Metamorphic success, measured as the proportion of pediveliger larvae that successfully become spat, is typically low in many hatcheries in the Chesapeake Bay region and especially in Maryland. Survival rates of pediveliger larvae to 5mm spat average less than 5% at the Horn Point hatchery of the University of Maryland. These rates are quite low compared tothose of several hatcheries in the Northeast which usually get 35 to 50% of pediveligers to 5 mm spat. Although many hypotheses have been proposed, many researchers believe that unsuccessful pediveligers lack certain nutritional or biochemical stores critical for surviving the stressful, nonfeeding metamorphic process. To test this hypothesis, various broods of larvae were transferred at different stages of development between the Horn Point hatchery and the Aquacultural Research Corp. (Dennis, Massachusetts) which usually experiences 50% metamorphic success with its oyster larvae.

A series of experiments was conducted in which oyster larvae were produced at both sites from broodstock representative of each facility. Subsequently, a series of larval transfers was conducted so that the effects of broodstock, spawning site, culture site (D-hinge through pediveliger), and setting site could be assessed. Samples of the larvae were taken every other day during development and after setting for determination of gross biochemical stores (protein, carbohydrate, and lipid). Differences in setting success and levels of biochemical stores were closely associated with the site at which the animals were raised, not where they were set. (Supported by the Northeast Regional Aquaculture Center.)

Toward a Sustainable Coastal Watershed:
The Chesapeake Experiment. Proceedings of a Conference
1-3 June 1994. Norfolk, VA
Chesapeake Research Consortium Publication No. 149

Effect of Environmental Conditions on the Population Structure of the Oyster: A Modeling Study

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Abstract: A size-structured, time-dependent population model has been developed to investigate growth and mortality of larvae and adults of *Crassostrea virginica*. In the coupled model, adult oysters spawn eggs into the water column, larvae develop from eggs to spat, and the spat are recruited to the benthic population as juveniles. Survivorship of both adults and larvae is influenced by both growth and mortality. Growth rates are regulated by four environmental factors: temperature, salinity, food concentration, and turbidity. Larval mortality is calculated as a cumulative loss based on known causes of larval mortality from both laboratory and field experiments. Adult oyster mortality is calculated from losses attributable to predation, fishing, disease, and extremes in environmental conditions.

Model results show that environmental conditions that are less than optimal for oyster and larval growth (e.g., low temperatures, low food concentrations and high turbidities) retard adult development and extend the larval period. Simulations using environmental conditions from Chesapeake Bay and Galveston Bay, Texas, show that oyster reproduction patterns in Chesapeake Bay are characterized by more discrete spawning events than in lower-latitude estuaries such as Galveston Bay. Additionally, the simulations show that in Chesapeake Bay there is a shorter window of time within which viable sets may occur each season. These differences in developmental rates, as well as in the pattern and frequency of reproductions, contribute to the temporal differences in recruitment patterns observed for Chesapeake and Galveston Bays.